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GUIDANCE ON REMEDIAL ACTIONS FOR CONTAMINATED GROUND WATER AT SUPERFUND SITES

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Submitted to:

Edwin F. Barth III, Task Manager
Hazardous Site Control Division
Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
Washington, D.C. 20460

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Dr. Craig Zamuda, Project Officer

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CONTENTS

CONTENTS (Continued)

WDR177/052

Section I

EXECUTIVE SUMMARY

This guidance focuses on key decisions in the development, evaluation, and selection of ground water remedial actions at Superfund sites.

The guidance emphasizes policy issues and a decisionmaking approach for ground water remedial actions, rather than technical aspects of ground water remediation.

The statutory and policy framework for ground water remedial actions are provided in CERCLA and the National Contingency Plan (NCP). The NCP compliance policy states that ground water remedial actions should attain or exceed applicable or relevant and appropriate Federal requirements, and that other Federal criteria, advisories, guidance, and state standards should be considered. The ground water protection standards under RCRA are often applicable or relevant and appropriate Federal requirements. In general, Superfund and RCRA share the same goals for protection of human health and the environment.

From the category of "guidance to consider," EPA's Ground Water Protection Strategy has a major impact on ground water remedial action process in Superfund. The Ground Water

Protection Strategy says that ground waters should be protected differentially based on characteristics of vulnerability, use and value. The ground water remedial action decision approach is consistent with the Ground Water Protection Strategy, with the development, evaluation, and selection of remedial alternatives linked to the characteristics of the ground water.

The development of remedial alternatives should be guided by specific performance criteria:

- o Remediation levels, or the level of ground water contaminant reduction achieved
- o Rate of restoration, or the time required to achieve remediation levels

A limited number of ground water remedial alternatives should be developed within a remedial action performance range, defined in terms of a range of potentially acceptable goals for remediation levels and remediation rate.

Specific performance based alternatives should be evaluated in Feasibility Studies, as appropriate:

- o A point of departure alternative, with a remediation level of 10^{-6} excess cancer risk, or threshold value for non-carcinogens in the ground water, within a short period of time (one to five years).

- Natural attenuation alternatives for situations where the plume has reached (or is in close proximity to) a receiving body of water. These alternatives should result in a 10^{-4} and a 10^{-6} excess cancer risk concentration level in the ground water (for carcinogens only).

- Plume containment alternatives for situations where the plume is not in close proximity to a receiving body of water. These alternatives should result in a 10^{-4} and 10^{-6} excess cancer risk concentration level in the ground water (for carcinogens only).

A limited number of additional alternatives with intermediate performance characteristics should also be developed.

The selection of a remedial action from the range of ground water remedial alternatives should be based on site-specific assessments of key evaluation factors. The factors that influence the decision for remediation concentration for carcinogens in the ground water are the following:

- o Other health risks borne by the affected population

- o Population sensitivities

Acute and chronic levels for noncarcinogens are not varied since they are threshold values.

The factors that influence the decision for the rate of restoration for carcinogens and non-carcinogens are:

- o Feasibility of providing an alternative water supply

- o Current use of ground water

- o Potential need for ground water

- o Effectiveness and reliability of institutional controls

- o Ability to monitor and control the movement of contaminants in ground water

Other factors that the decisionmaker must evaluate for determining the appropriate ground water protection goals for carcinogens and noncarcinogens are:

- o Limiting extent of contamination
- o Impact on environmental receptors
- o Technical practicability of implementing the alternative
- o Cost of the alternative

Discussions on each of these factors focus on site-specific conditions that should guide the decisionmaker in selecting a ground water remedial action. These discussions emphasize conditions which indicate the need for highly protective and/or rapid remediation, as well as those conditions which provide flexibility to select a remedy that achieves a less protective remediation level, or that requires a longer time to restore the aquifer.

The actual performance of a ground water remedial action is difficult to predict until the remedy has been implemented and operational data have been assessed. Superfund promotes a flexible decision process for ground water remedial actions to respond to differences between design and actual performance. At sites where actual performance lags behind design performance, the decisionmaker should review the assumptions that led to the selection of the remedy. The decisionmaker should then determine whether to continue the existing remedial action and revise the performance objectives for the site; to upgrade the remedial action in order to meet the original performance goals, or to terminate the remedial action if there is no longer a threat to human health or the environment.

A large section of the guidance document is devoted to case studies. These are hypothetical scenarios that demonstrate key features of the ground water remedial action decision process. The studies focus on the significance of ground water classification in the evaluation of alternatives, evaluation of other cost-effectiveness factors, as well as the use of the performance range for analyzing ground water remedial alternatives.

WDR178/002

Section II

INTRODUCTION

PURPOSE AND OBJECTIVES

This guidance focuses on key decisionmaking issues in the development, evaluation, and selection of ground water remedial actions at Superfund sites.

The principal objectives of this guidance are to:

- Outline key considerations to be addressed when selecting a ground water remedy from the range of alternatives screened in the FS

- Outline a consistent approach to making cost-effectiveness decisions for contaminated ground water remediation

- Present case studies as examples of how the ground water cleanup decisionmaking process should be applied

Technical aspects of ground water investigation, evaluation, and remediation are not discussed in detail. The user is referred to other resources that address these technical concerns.

This guidance document has been prepared as a resource for three groups: (1) contractors planning and executing remedial investigations and feasibility studies (RI/FSs) at Superfund sites where ground water has been contaminated, (2) EPA regional project managers (RPMs) responsible for the quality and completeness of RI/FSs, and (3) RPMs and other decision-makers responsible for the selection and subsequent performance evaluation of ground water remedial actions at Superfund sites.

Each Superfund site presents a unique set of environmental and public health conditions and problems. It is important, however, that decisionmakers consider the same factors and follow a consistent approach when selecting a cost-effective remedy. Consideration of the issues presented in this guidance and the use of the decisionmaking approach is intended to provide a reasonable level of consistency in ground water remedial actions taken at sites with similar contamination problems that pose similar threats to public health and the environment.

OVERVIEW OF THE REMEDIAL PROCESS

The Superfund process involves a series of steps beginning with the identification of site problems during the preliminary assessment/site inspection (PA/SI); continuing through site characterization in the RI, development and screening of remedial alternatives, and detailed analysis of screened remedial alternatives in the FS; and culminating in the selection, implemention, and operation of a remedial action. Comprehensive guidance on performing the RI/FS portion of the process is provided in two U.S. EPA documents: Guidance on Remedial Investigations Under CERCLA (1985) ("Remedial Investigation Guidance") and Guidance on Feasibility Studies Under CERCLA (1985) ("Feasibility Study Guidance").

The RI and FS guidance documents describe the general steps necessary to complete an RI/FS at a Superfund site and include a level of detail sufficient to describe the components of each step and how the steps are integrated. The guidance presented here ("Ground Water Guidance") should allow the user to apply the RI and FS guidances to site-specific ground water contamination conditions, focusing on decision points that apply specifically to remedial actions for contaminated ground water. These points where decisions must be made include:

- Establishment of response objectives

- Development of remedial alternatives

- Selection of a cost-effective alternative (decision analysis)

- Evaluation of remedial action performance

- Determination that the remedy is complete

Figure II-1 shows the Superfund remediation process and identifies where these decision points fit in to the process as a whole. Figure II-2 provides an overview of the alternative selection process that is specific to ground water.

This guidance discusses a performance range for ground water response actions. The performance range is defined by the remediation level and time required for remediation. Various remedial approaches can be applied to the performance range to identify the individual alternatives.

RELATIONSHIP TO SOIL ACTION

Although this Ground Water Guidance is medium-specific, it is not implied that contaminated ground water can be evaluated or remediated independently of other media. Waste or contaminated soils are potential sources of contaminants in ground water. The development of a cost-effective remedial

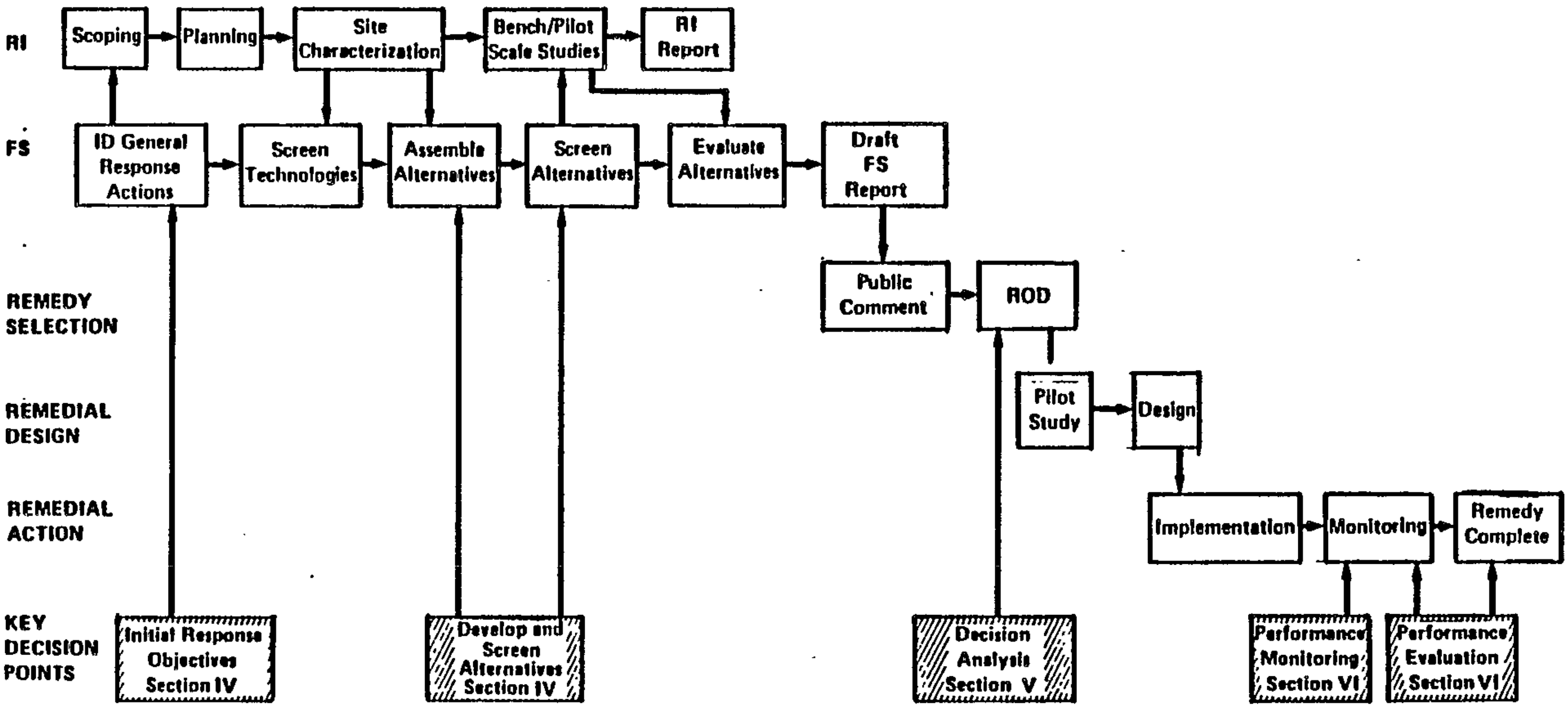

Figure II - 1

DECISION POINTS IN THE SUPERFUND PROCESS

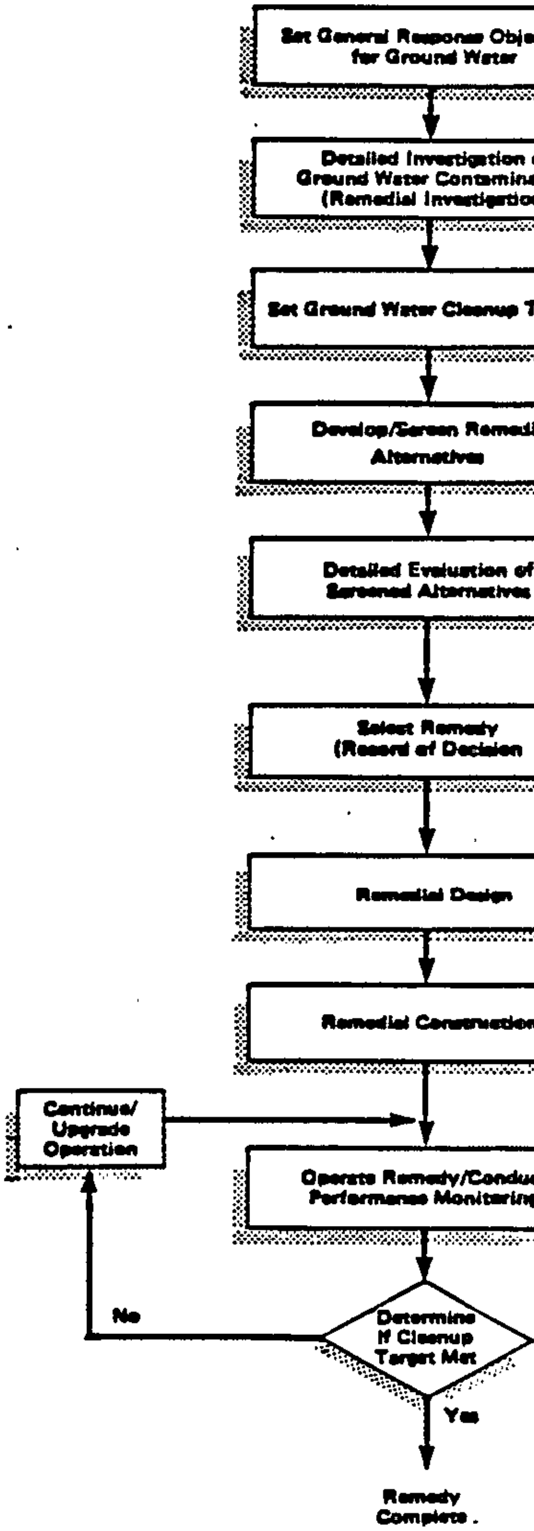

Figure II - 2

OVERVIEW OF THE REMEDIAL ALTERNATIVE SELECTION PROCESS alternative must be based on an understanding of the interactions between contaminated soils and ground water.

The cost-effectiveness of a source control alternative or a ground water alternative can be analyzed as a separate operable unit. However, the cost-effectiveness of a remedial action that combines source control and ground water restoration is not simply a sum of its parts. In general, source control measures should facilitate the achievement of the long-term objectives and goals for remediation of the ground water. In order to address adequately the concerns for the ground water, a range of source control actions should be considered.

OTHER GUIDANCE DOCUMENTS
APPLICABLE TO REMEDIAL ACTIONS UNDER SUPERFUND

This Ground Water Guidance is intended to provide users with information necessary to apply the RI and FS guidance at Superfund sites with ground water contamination problems. This document is one of a number of similar reports that are designed to aid in the Superfund decisionmaking process.

The Guidance on Data Quality Objectives in Superfund (under preparation) discusses data quality objectives for sampling and analysis. The CERCLA Compliance With Other Environmental

Statutes (Draft, 12/10/85) discusses requirements for consistency with other environmental laws. The Endangerment Assessment Guidance (1985) clarifies the requirements for an endangerment assessment, which must be developed to support administrative and judicial enforcement actions taken under Superfund. The RCRA Ground-Water Monitoring Technical Enforcement Guidance Document (Draft, 1985) discusses technical elements of hydrogeologic investigations that may be applied at Superfund sites. Models used to estimate potential releases, migration, and exposures to contaminants at Superfund sites are evaluated in the Superfund Exposure Assessment Manual (Draft, 12/18/85). The Superfund Public Health Evaluation Manual (Draft, 1/14/86) discusses procedures for selecting indicator chemicals, estimating chemical intakes, and evaluating resultant potential public health impacts. These components are critical to the development, evaluation, or selection of remedial alternatives for ground water.

ORGANIZATION OF THE GUIDANCE

While each section of this document can be used individually for a certain portion of the RI/FS process, the sections are best used together for a fuller understanding of the policy.

Section III. Statutory and Policy Framework for Ground Water Remedial Alternatives

Section IV. Development of Alternatives

Section V. Decision Analysis

Section VI. Evaluating Performance and Modifying Remedial Actions

Appendix A. Case Studies and Case Histories

Appendix B. Strategy for Ground Water Contamination Due to Multiple Sources (omitted from this draft)

Section III discusses specific elements of CERCLA and the NCP that establish the policy for ground water remedial actions under Superfund. Section IV describes the remedial action performance range and then focuses on the development of alternatives. Section V discusses key factors that the decisionmaker should evaluate in selecting a remedial action, and how the results of these evaluations should guide the selection. Section VI discusses the elements of ground water remedial action performance monitoring and evaluation, and how this information can be used in determining whether a remedial action is performing satisfactorially and should be continued without modification, whether it should be upgraded, or whether performance objectives have been met and the remedy is complete. Appendix A presents six case studies, using hypothetical sites to demonstrate application of the guidance.

The ground water remedial action issues discussed in this guidance are primarily applicable to Superfund sites where there are identifiable plumes. A number of sites on the National Priorities List are categorized as multiple-source ground water contamination problems. At multiple source sites, releases from sources other than the Superfund site contribute to ground water contamination. In order for a ground water remedial action that cleans up or controls releases from the Superfund site to be effective, it must be combined with corrective actions for other contaminant sources. Ground water remediation at these multiple source sites may involve coordination with other agencies and authorities outside of Superfund. An EPA memorandum on multiple-source ground water contamination sites will be presented in an Appendix B to the final version of this document, but it is not included in this draft. This memorandum will provide interim guidance on RI/FS and remedial response activities at multiple-source Superfund sites.

WDR176/013

Section III

STATUTORY AND POLICY FRAMEWORK FOR GROUND WATER REMEDIAL ALTERNATIVES

INTRODUCTION

Under CERCLA and the revised National Contingency Plan (NCP), EPA's policy concerning the cleanup of hazardous waste sites and the applicability of other environmental laws is set.[1] The NCP specifies that management of migration measures (actions that are taken to minimize and mitigate the migration of hazardous substances or pollutants or contaminants and the effects of such migration) may be required to address contamination that has migrated away from the original location. Ground water actions are considered management of migration measures and are subject to the appropriate NCP requirements for compliance with other environmental statutes. A number of requirements and policies must be considered when evaluating ground water remedial actions. These include RCRA, the Safe Drinking Water Act, the Clean Water Act, and the Ground Water Protection Strategy.

[1]The "compliance policy" is discussed in detail in the preamble to the revised NCP, which was printed in the Federal Register on November 20, 1985 (50 FR, 47917-47926). The preamble also includes a memo on the compliance policy sent from J. Winston Porter, Assistant Administrator, OSWER, to the EPA Regional Administrators on October 2, 1985 (50 FR, 47946-47950).

REQUIREMENTS OF THE NATIONAL CONTINGENCY PLAN

The NCP establishes EPA's policy concerning the basis for determining remediation levels and the range of alternatives to consider during a FS.

REQUIREMENTS FOR REMEDIATION LEVELS

NOTE: This section may be changed in response to the CERCLA reauthorization requirement to meet State standards.

The NCP establishes policy to attain or exceed applicable or relevant and appropriate Federal requirements and to consider other Federal criteria, advisories, and guidance and State standards (40 CFR 300.68). Applicable requirements are those Federal requirements that would be legally applicable, whether directly or as incorporated by a Federally authorized State program, if the response actions were not undertaken pursuant to CERCLA Section 104 or 106.

Relevant and appropriate requirements are those Federal requirements that, while not "legally applicable," are designed to apply to problems sufficiently similar to those encountered at CERCLA sites that their application is appropriate.

Other factors to be considered include standards, criteria, advisories, and guidance developed by EPA, other Federal agencies, or the States that may be useful in developing site remedies.

The Draft Guidance on CERCLA Compliance With Other Environmental Statutes describes general procedures for determining whether a requirement is applicable or relevant and appropriate. The preamble to the NCP specifies that when relevant and appropriate requirements are used, they are intended to have the same weight and consideration as applicable requirements.

RANGE OF SCREENED ALTERNATIVES

The revised NCP (40 CFR 300.68) establishes a policy that the FS include an evaluation of the no-action alternative plus alternatives that attain, exceed, or do not attain applicable or relevant and appropriate requirements.

Ground water remedial alternatives that fall within the performance range defined later in this document are considered to attain or exceed applicable or relevant and appropriate requirements. However, the NCP lists special circumstances or exceptions under which it may be appropriate to select an alternative that does not attain relevant or applicable standards and criteria. These exceptions are discussed in Section IV, Decision Analysis.

APPLICATION OF RCRA GROUND WATER PROTECTION STANDARDS TO SUPERFUND

The ground water protection standards under RCRA (40 CFR 264.90-264.109, Subpart F, Ground Water Protection) may be applicable or relevant and appropriate to remedial actions for contaminated ground water at Superfund sites. Determinations of ground water restoration levels under both RCRA and Superfund may be based on a site-specific risk assessment.

THE SAFE DRINKING WATER ACT

Maximum Contaminant Levels (MCLs) developed under the Safe Drinking Water Act (SDWA) are applicable requirements for drinking water sources. Section IV discusses use of MCLs in setting remediation levels. However, since MCLs were developed using cost and technical considerations, they may be less stringent than standards or criteria derived only from public health considerations. More protective levels may be appropriate in some cases.

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EPA is in the process of expanding the list of drinking water standards. In 50 FR 46902 (November 13, 1985), EPA provided a list of proposed MCLs. The SDWA Amendments of 1986 establish a schedule for finalizing these proposed MCLs.

EPA has also developed recommended maximum contaminant levels (RMCLs), which are entirely health-based. The first RMCLs appeared in 50 FR 46936 (November 13, 1985). The SDWA Amendments of 1986 refer to RMCLs as maximum contaminant goals which will serve as guidance for establishing drinking water MCLs. RMCLs are classified as "other criteria to be considered" when setting cleanup levels.

THE CLEAN WATER ACT

Requirements under the Clean Water Act (CWA) will impact permitting requirements and discharge limits for remedial actions that involve the discharge of contaminated ground water, either treated or untreated. The CWA regulates discharges to surface waters, publicly owned treatment works, and to the ground via underground injection. Ambient water quality criteria (45 FR 79318, November 28, 1980) established under the CWA provide guidance on acceptable levels of contaminates for protection of human health and for protection of aquatic life.

THE GROUND WATER PROTECTION STRATEGY

The importance of ground water is strongly influenced by its current and potential use. This concept is central to the ground water classification system defined in EPA's Ground Water Protection Strategy (August 1984). The Ground Water Protection Strategy is listed in the NCP among the other criteria, standards, and guidance to be considered in Superfund.

The policy under the Ground Water Protection Strategy establishes ground water protection goals based on "the highest beneficial use to which ground water having significant water resources value can presently or potentially be put." Guidelines for protection are established for three classes of ground water based on value and vulnerability to contamination:

Class I: Special Ground Waters are those that are: (1) highly vulnerable to contamination because of the hydrological characteristics of the areas where they occur, and (2) characterized by either of the following factors:

- The ground water is irreplaceable, in that no reasonable alternative source of drinking water is available to substantial populations.

- The ground water is ecologically vital, in that the aquifer provides the base flow for a particularly sensitive ecological system that, if polluted, would destroy a unique habitat.

Class II: Current (IIA) and Potential (IIB) Sources of Drinking Water and Waters Having Other Beneficial Uses include all other ground waters that are currently used or are potentially available for drinking water or other beneficial use.

Class III: Ground Waters Not Considered Potential Sources of Drinking Water and of Limited Beneficial Use are ground waters that are highly saline, i.e., they have total dissolved solids (TDS) levels over 10,000 mg/l, or are otherwise contaminated beyond levels that allow cleanup using methods reasonably employed in public water treatment systems. These ground waters also must not migrate to Class I or II ground waters or have a discharge to surface water that could cause degradation.

The classification is based on the characteristics of ground water underlying a certain area, which is likely to extend beyond the boundaries of a specific contaminant plume.

It is expected that individual states will develop ground water classification systems. A state's classification system may be used once it has been deemed equivalent or as least as stringent as the system established in EPA's Ground Water Protection Strategy. In the interim, EPA's system will apply.

WDR149/030

Section IV

DEVELOPING REMEDIAL ALTERNATIVES

INTRODUCTION

This section presents guidelines for developing a reasonable range of remedial alternatives for sites with contaminated ground water. Detailed guidance on the development of alternatives is provided in Chapter 2 of the Feasibility Study Guidance. These procedures are intended to supplement the Feasibility Study Guidance by providing additional considerations specifically for ground water alternatives. The process described here focuses on development of performance-based alternatives.

The following steps should be used for the development of alternatives:

- Establish a range of site response objectives
- Establish a range for remediation targets
- Determine response actions
- Formulate alternatives

In actual project applications, this sequence of steps may be iterated at various stages of the Superfund process:

- During the RI to assist in planning cost-effective RI activities

- During preliminary stages of the FS

- During detailed evaluation in the FS

This iterative approach allows a project to respond to changes in conditions (based on new data) and other changes in project needs. This process should ultimately result in detailed evaluation of a limited number of alternatives with varying remediation targets. The factors used to evaluate the alternatives and select a ground water remedy are discussed in Section V.

RESPONSE OBJECTIVES

Response objectives are site-specific, qualitative, initial cleanup objectives that are established based on the nature and extent of the contamination, the resources that are currently and potentially threatened, and the potential for human and environmental exposures. A partial list of response objectives for contaminated ground water at Superfund sites is presented in Table IV-1. This list covers many of the situations encountered at Superfund sites.

Table IV-1
REMEDIAL ACTION RESPONSE OBJECTIVES FOR GROUND WATER

1. Prevent exposure to contaminated ground water

   o An alternate water supply may be required for the population with existing wells affected by the contaminant plume. The alternate water supply may be developed for interim use during remedial actions or for permanent use where the aquifer is not restored

   o Institutional controls to restrict access to the contaminant plume

2. Protect uncontaminated ground water for current use

   o Prevent contamination of existing wells downgradient of the plume and/or in adjacent aquifers

3. Protect uncontaminated ground water for future use

   o Minimize migration and spread of contaminants within the aquifer

   o Minimize migration and spread of contaminants to adjacent aquifers

4. Restore contaminated ground water for future use

   o Reduce contaminant concentrations in the plume to levels that are safe to drink

5. Protect environmental receptors

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However, other response objectives may be appropriate based on site-specific conditions.

Response objectives are developed in the initial phase of the FS and are used as the framework for developing detailed remedial alternatives. Response objectives are formulated based on the goal of the Superfund program to protect public health and the environment by either (1) restoring potentially usable contaminated ground water to, and protecting usable uncontaminated ground water at, levels that are safe for present and potential users and/or environmental receptors, or (2) preventing exposure to ground water contaminated above health-based levels. The preference of the Superfund program is to restore and protect usable ground water. The specificity of these objectives may vary based on the degree of information on site conditions and the complexity of the site.

PERFORMANCE CRITERIA

The primary performance criteria for remedial actions for contaminated ground water include:

- Remediation levels or the level of protection to be achieved

- o Rate of restoration or time required to achieve remediation levels

REMEDIATION LEVELS

NOTE: This section may be changed in response to the CERCLA reauthorization requirement to meet State standards.

Remediation levels are developed to define the allowable concentrations in ground water at the completion of the response action. Remediation levels for ground waters with Class I or Class II characteristics are established to provide protection of human health and the environment. Primary sources for health-based criteria include MCLs, RMCLs, and health advisories under the SDWA; and ambient water quality criteria (AWQC) under the Clean Water Act. These AWQC also include levels in surface waters that are protective of aquatic life. If health-based criteria are not available for the contaminants of concern, remediation levels can be determined through a site-specific risk assessment, using procedures described in the Superfund Public Health Evaluation Manual.

Remediation levels for noncarcinogens are based on reference doses. These are threshold values derived from quantitative information available from toxicological or epidemiologic data on the relationship between intake of a contaminant and toxic effects. The Superfund Public Health Evaluation Manual describes a hazard index approach to assess the overall potential for noncarcinogenic effects posed by multiple threshold chemicals.

Carcinogens do not have threshold values and remediation targets for carcinogens are based on calculated health risks. At sites where both carcinogens and noncarcinogens are present, remediation levels for carcinogens are typically lower than acceptable concentrations for noncarcinogens and are more likely to determine the extent of the remedial action. Alternatives should be developed that achieve acceptable intakes for noncarcinogens, achieve excess lifetime cancer risks across the risk range of 10^{-4} to 10^{-7} for carcinogens, and are protective of the environment. Section V discusses the factors the decisionmaker should consider when selecting the remediation level.

For multiple hazardous constituents in ground water, risk characterization is based on total intakes (all exposure pathways) of all contaminants. Procedures for calculating exposures and risks are described in the Superfund Public Health Evaluation Manual.

For contaminants that have an MCL and are carcinogens, alternatives should be developed that achieve remediation levels within the cancer risk performance range (10^{-4} to 10^{-7} excess lifetime cancer risk), even though the MCL may be out of the risk range.

Indicator Chemicals

At sites where there are many hazardous substances in the ground water, a public health evaluation that includes all of the identified chemicals may be impractical and unnecessary. The Superfund Public Health Evaluation Manual describes procedures for selecting indicator chemicals based on toxicity and concentration. For remedial action decision-making, the indicator chemical selection criteria should be expanded to include the mobility, treatability, and total mass of contaminants. These additional criteria may be critical in the development and evaluation of remedial alternatives.

Environmental Protection

In certain situations, remediation levels that are set to protect public health may not adequately protect the environment, and environmental criteria and/or toxicity data for fish and wildlife should be evaluated along with human health criteria. For example, certain aquatic species may be threatened by contaminant concentrations that are protective of public health. At other sites, there may be no human

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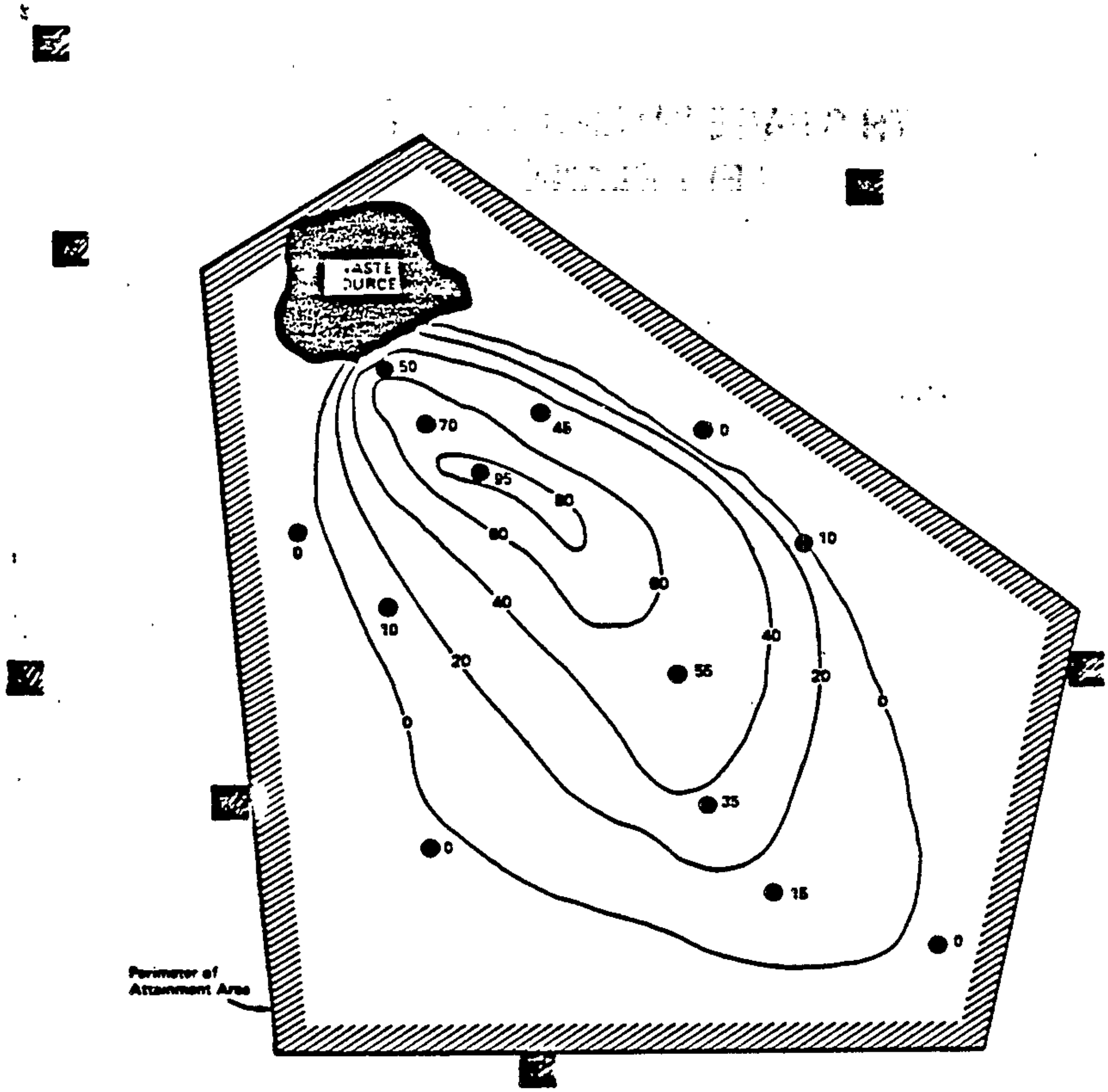
exposure, but environmental receptors such as wildlife may be adversely affected by contaminants. Therefore, the potential environmental impacts should be reviewed when selecting remediation levels to determine if environmental threats will override human health concerns. Ambient water quality criteria from the Clean Water Act includes contaminant levels that are considered protective of aquatic life. In the Case Studies (Appendix A), Site 5 involves a remedy selection based on environmental protection.

RATE OF RESTORATION

The rate of restoration is defined in terms of the period of time required to achieve the remediation level in the ground water at all locations within the contaminant plume beyond the waste source. This area between the waste source and the boundary of the plume is referred to as the area of attainment, as shown in Figure IV-1. Alternatives should be developed that achieve remediation levels within the risk range over a range of time periods.

GENERAL RESPONSE ACTIONS

The next step in alternative development is to identify and match response actions to response objectives and remediation targets.



LEGEND

- ● 45 Monitoring Well Location and Contaminant Concentration
- (40) Contour of Contaminant Concentration
- ■ Ground Water User
- Perimeter of Attainment Area

Figure IV - 1

CONCEPTUAL DIAGRAM OF WASTE SOURCE, CONTAMINANT PLUME, AND ATTAINMENT AREA

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Categories of general response actions for contaminated ground water include active restoration, containment through gradient control, and natural attenuation. A response action may involve aspects of each of these categories.

These general response actions may be combined with institutional (or management) controls to protect public health until such time that contaminants in ground water have been reduced to a level that is safe for consumption. The applications of these general response actions are discussed below.

ACTIVE RESTORATION

Active restoration generally refers to the use of an extraction system to remove contaminated water from the aquifer, followed by treatment (if required) and discharge or reinjection back into the aquifer. Restoration may also be achieved in-situ through the injection of additives to enhance degradation in the subsurface environment. However, most in-situ technologies are still in the developmental stage. Active restoration actions reduce ground water contaminant levels more rapidly than plume containment or natural attenuation. Factors that potentially favor the use of active restoration include:

- Mobile contaminants

- Moderate to high hydraulic conductivities in the contaminated aquifer

- Effective treatment technologies available for the contaminants in the ground water

PLUME CONTAINMENT

Plume containment refers to minimizing the spread of a contaminated plume through hydraulic gradient control or barrier walls, or by combining these technologies. These options rely on the prevention of exposure for the protection of public health. Slow contaminant removal (for gradient control systems) or natural attenuation are used to gradually achieve remediation levels within the contained area. There are a number of conditions that potentially favor the use of a containment alternative:

- Ground waters that are naturally unsuitable for consumptive use (e.g., Class III aquifers)

- Low mobility contaminants

- Low aquifer permeability

- Contaminants are not present at highly toxic concentrations

- Low potential for exposure

- Complex hydrogeologic conditions that make it infeasible to actively restore the contaminant plume

- Projected demand for future use of the ground water is low

NATURAL ATTENUATION

Natural attenuation relies on the ground water's natural ability to lower contaminant concentrations through physical, chemical, and biological processes until cleanup levels are met. A natural attenuation response action will also encompass continuing liability for the ground water, monitoring to track the direction and rate of movement of the plume, and responsibility for maintaining effective, reliable institutional controls to prevent use of the contaminanted ground water. There are a number of conditions that potentially favor the use of natural attenuation:

- Ground waters that are naturally unsuitable for consumptive use (e.g., Class III aquifers)

- Contaminants degrade quickly, or are not present in highly toxic concentrations

- Low potential for exposure

- Complex hydrogeologic conditions that make it infeasible to actively restore the contaminant plume

- Projected demand for future use of the ground water is low

- Close proximity to a surface water discharge area, with dilution to levels that are protective of human health and the environment

The primary criterion for selecting between a natural attenuation or plume containment alternative is the proximity of the contaminant plume to a surface water discharge area. Where the plume would migrate a considerable distance before reaching the discharge point, thus significantly increasing the area of ground water contamination, a plume containment alternative is generally preferred over natural attenuation.

REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

A range of remedial technologies and process options can be combined under a particular general response action. Figure IV-2 provides an overview of some of the technologies

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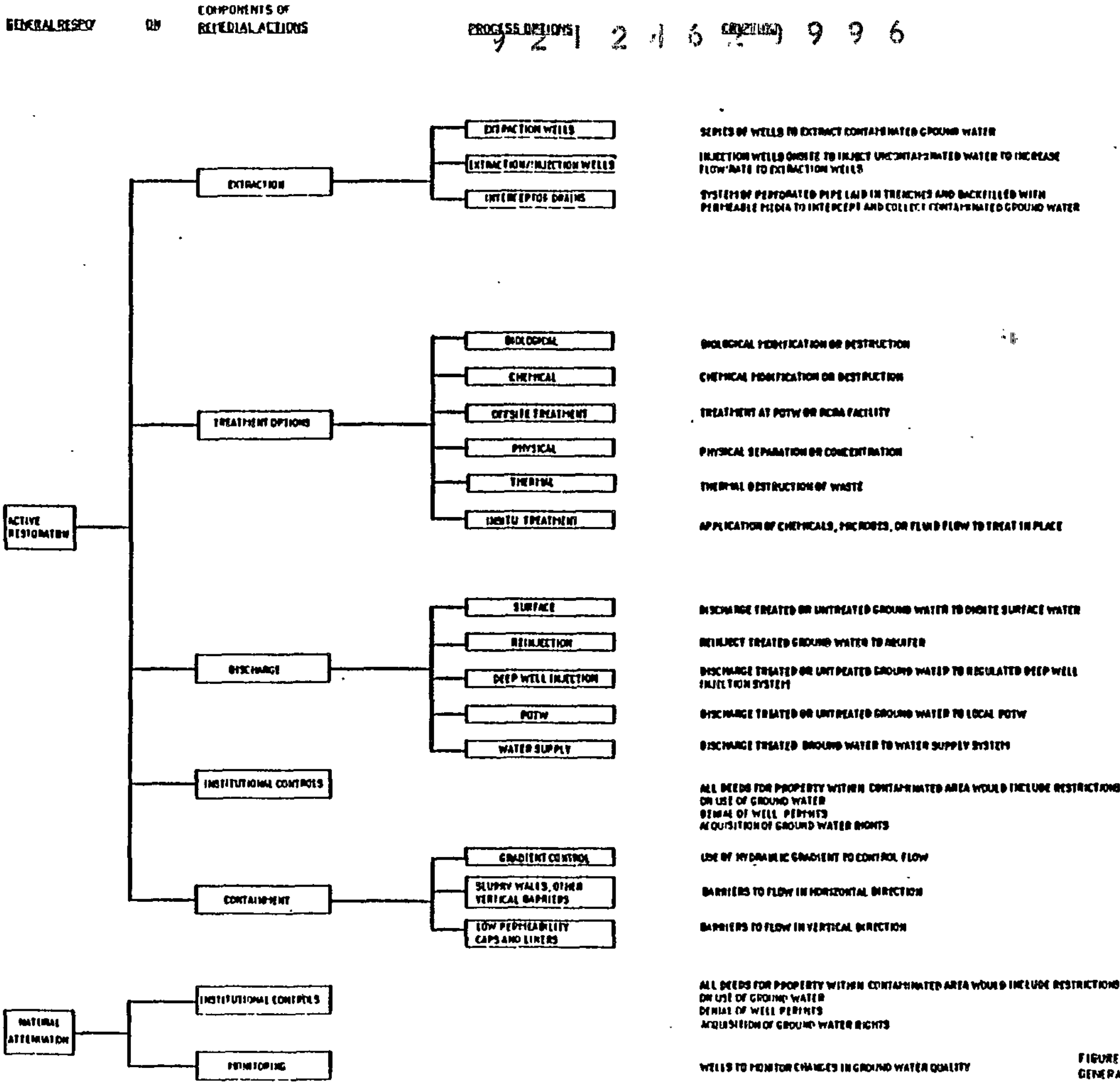

FIGURE IV-2
GENERAL RESPONSE ACTIONS AND PROCESS OPTIONS FOR GROUND WATER

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and process options available for a ground water remedial action. Alternatives are built from combinations of these various technologies.

The components that are used as part of restoration actions may include extraction, containment, discharge, and institutional controls. Containment refers to minimizing the spread of a contaminated plume through pumping to control hydraulic gradients or through the construction of low-permeability barriers.

The scope of this guidance document does not include a technical discussion of the various technologies. Uses and limitations of these technologies are discussed in the EPA Handbook for Remedial Action at Waste Disposal Sites (October 1985).

THE DEVELOPMENT AND SCREENING OF ALTERNATIVES

PERFORMANCE RANGE

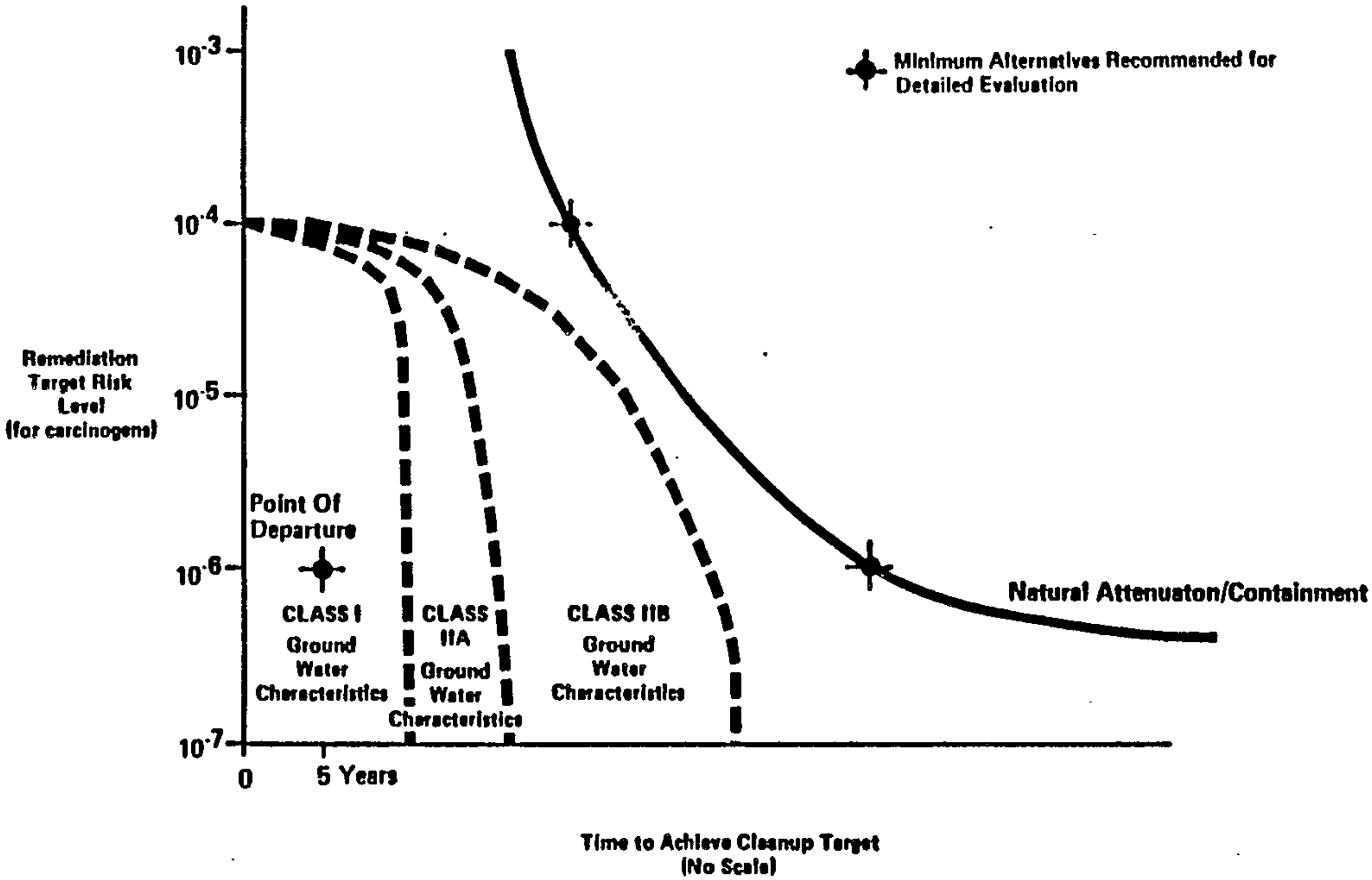
The final step in the alternatives development process is to select a limited number of alternatives within the remedial action performance range. In general, this approach for selecting alternatives applies to aquifers having characteristics of Class I and II ground waters. Class III ground waters are treated as a special case and are described later. Typically, alternatives for three to five points in the performance range will be evaluated in detail. The performance range, shown conceptually in Figure IV-3, is defined as follows:

- Remediation targets for carcinogens range between 10^{-4} and 10^{-7} excess lifetime cancer risk; remediation targets for noncarcinogens are set according to available standards or criteria.

- Remediation targets are achieved within an acceptable period of time in the area of attainment.

- The remedy meets all applicable or relevant and appropriate requirements.

There is no single appropriate distribution of "points" within the performance range that the remedial alternatives should achieve. That distribution will depend on the types and combinations of remedial technologies considered and the scale or operating criteria for the remedial alternative. Either active restoration or natural attenuation may achieve remediation targets within the performance range. It is the responsibility of the FS contractor to develop feasible, reliable, and cost-effective remedial alternatives within the performance range.



Notes: Ground waters with characteristics of Class I aquifers are expected to be restored most rapidly. Ground waters with Class IIB characteristics would typically be restored more slowly because of the reduced potential for immediate exposure.

In general the remedial alternatives developed are "bounded" by the point of departure alternative and the natural attenuation/containment remedies at the 10^{-4} and 10^{-6} risk levels.

The remediation levels for noncarcinogens are established based on threshold levels rather than a risk range.

Figure IV - 3
PERFORMANCE RANGE FOR GROUND WATER REMEDIAL ALTERNATIVES

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Point of Departure Alternative

At least one remedy should match the point of departure remedial alternative for ground waters with Class I or II characteristics. The point of departure alternative is characterized as follows:

- The remediation target is the 10^{-6} excess lifetime cancer risk (based on all potential pathways of exposure), meets reference doses and all applicable or relevant and appropriate requirements.

- The remediation target is achieved within a short time period (approximately one to five years) throughout the area of attainment.

Other Alternatives Within the Performance Range

Additional alternatives should be developed within the performance range to ensure that the decisionmaker can select from an adequate range of alternatives. Where the plume is currently discharging to a surface water body, or is in close proximity to the discharge point, the following alternatives should be developed.

- Natural attenuation until a 10^{-4} excess lifetime cancer risk is achieved.

- o Natural attenuation until a 10^{-6} excess lifetime cancer risk is achieved.

Where the existing plume would migrate a considerable distance before reaching a surface water discharge point, thus significantly increasing the area of ground water contamination, the following alternatives should be evaluated:

- o Plume containment measures until a 10^{-4} excess lifetime cancer risk is achieved

- o Plume containment measures until a 10^{-6} excess lifetime cancer risk is achieved

CLASS III GROUND WATERS

If a Superfund site has ground waters with Class III characteristics (i.e., ground water that is unsuitable for human consumption) the performance range concept may not apply. Rather, alternatives should be developed based on the specific site conditions. Environmental receptors and systems must be considered when evaluating alternatives for contaminated Class III ground waters to ensure that no adverse environmental impacts occur. In ground waters with Class III characteristic, environmental protection may determine the necessity and extent of ground water remediation. In general, alternatives for Class III ground waters will be relatively limited and the evaluation less extensive than for Class I or II ground waters. In the Case Studies (Appendix A), Site 6 involves a remedy selection where Class III ground waters have been contaminated.

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Section V

DECISION ANALYSIS

INTRODUCTION

As described in Section IV, a range of alternatives should be developed for contaminated ground waters with Class I or Class II characteristics that are expected to achieve remediation levels at standards or at health-based threshold levels for noncarcinogens, within the 10^{-4} to 10^{-7} risk range for carcinogens over a range of time periods, and through various remedial approaches (e.g., pumping and treatment, plume containment, natural attenuation). The cost effectiveness of all alternatives should be analyzed as required by statute and the NCP, and as laid out in the Feasibility Study Guidance. The results of this analysis provide the basis for determining the appropriate remedy in the ROD.

The selection of a remedial action for ground water is a cost-effectiveness decision. This decision should be based on careful evaluation and comparison of alternatives with respect to a number of important factors. This section outlines cost-effectiveness evaluation factors and discusses how those factors are applied in the remedy selection process. The Case Studies (Appendix A) provide ground water contamination scenarios that show the application of the decision process.

REMEDIAL ALTERNATIVE EVALUATION FACTORS

Ground water response actions should be formulated based on a site-specific assessment of key evaluation factors. Some or all of the following factors are expected to be significant at many Superfund sites:

- Feasibility of providing an alternative water supply to meet current ground water needs

- Potential need for the ground water

- Effectiveness and reliability of institutional controls

- Ability to monitor and control the movement of contaminants in ground water

- Other health risks borne by the affected population and population sensitivities

- Cost of remedial alternatives

- Technical limits of ground water restoration
- Impacts on environmental receptors
- Potential for spreading of the contaminant plume

Analysis of these factors should guide the decisionmaker in selecting the level of remediation and the period of time required to complete the ground water response action. Some of these factors are most significant in determining the importance of rapidly remediating the ground water. Other factors are most significant in determining the appropriate level of remediation.

In the following discussion, these factors have been divided into three groups: remediation rate factors, remediation level factors, and other factors which affect both aspects of remedial action performance.

REMEDIATION RATE EVALUATION FACTORS

Feasibility of Providing an Alternative Water Supply to Meet Current Ground Water Needs

At sites where current ground water users will be affected by the continued migration of a contaminant plume, decisionmakers should consider the feasibility of providing alternative water supplies during a remedial action, and the properties of these potential alternative water sources. Specifically, the decisionmaker should consider the following:

- The time and cost required to develop an alternative water supply

- The quality of the alternative water supply

- The reliability of the alternative water supply, particularly in terms of susceptibility to contamination

- The sustainable quantity, or safe yield of the water supply, considering the water use demands of those current users affected by the site, plus any current or potential competing demands

- Whether the alternative water supply is itself irreplaceable (i.e., is there a "backup" to that alternative source).

A readily accessible water supply of sufficient quality and yield that is protected from sources of contamination may reduce the importance of rapid remediation, giving the decisionmaker more flexibility to select a response action that requires a longer time to achieve the selected remediation level. The presence of a backup source to the alternative water supply adds substantially to the reliability of an alternative supply.

Potential Need for Ground Water

If ground water contaminated from a Superfund site is not currently used but is a potential source of drinking water (characteristics of Class IIB ground waters), the decision-maker should evaluate that potential need in terms of timing (i.e., when a demand for that ground water is anticipated), the extent of that potential need (in terms of volume) the type of need (drinking water, irrigation, manufacturing, etc.), and the availability and characteristics of other water sources in the same area. Where a demand for high quality ground water (e.g., drinking water) is anticipated in the near future, and other potential sources are either not available or are of insufficient quality or quantity, the decisionmaker should emphasize remedies that rapidly achieve remediation levels appropriate for that anticipated need.

Concrete predictions of potential need are clearly impossible, and the decisionmaker faces a difficult task in assessing this factor. The decisionmaker should make reasonable, conservative assumptions on type, timing, and extent (i.e., volume) of potential need for the contaminated ground water, and use this evaluation to guide decisions concerning the rate of remediation of the contaminated ground water.

Effectiveness and Reliability of Institutional Controls

Institutional controls restricting ground water use should be implemented as part of the response action at all sites where exposure poses a potential threat to human health. The effectiveness and reliability of these controls should be evaluated in determining the appropriate emphasis on rapid remediation. Where the decisionmaker determines that there is adequate certainty that controls will be effective and reliable, there is more flexibility to select a response action that requires a longer period to achieve remediation levels. Conversely, if it is unclear that there is an authority to establish controls, or that there is an effective and reliable enforcement mechanism, the decisionmaker should place an emphasis on response actions that rapidly restore the aquifer.

Ability to Monitor and Control the Movement of Contaminants in Ground Water

The ability to monitor and control the movement of contaminants in ground water depends on the complexity of the hydrogeologic system and the quality of the hydrogeologic investigation. In a hydrogeologic system that is relatively simple, and where ground water flow paths and the distribution of contaminants in the ground water are well characterized predictions of remedial action performance are more reliable. This increased reliability provides the decision-maker with more flexibility to select a remedial alternative that requires more time to achieve remediation levels.

Where flow patterns are complex and the hydrogeologic system is difficult to characterize, the potential for unanticipated migration pathways to develop increases, which may reduce the effectiveness of the remedial action. Remedial actions that rapidly restore ground water should be emphasized in these situations.

REMEDIATION LEVEL EVALUATION FACTORS

Other Health Risks Borne by the Affected Population, and Population Sensitivities

If the population affected by contaminated ground water from a Superfund site has been exposed to potentially hazardous levels of carcinogens for a significant period of time, either from the site or from other sources, emphasis should be placed on remedial actions that reduce carcinogen levels to the highly protective end of the risk range (10^{-6} to 10^{-7} excess lifetime cancer risk). Remediation levels for noncarcinogens should be set considering exposures from other sources, with the goal of reducing total exposures to no effect levels. For example, at the Reilly Tar Superfund site the population had been exposed to contaminated ground water for an undetermined period of time. This prior exposure influenced the decision to use a more protective concentration level.

Similarly, if a significant portion of the affected population is unusually sensitive to hazardous chemicals (e.g., young children, the elderly), remediation levels should be highly protective. Reference doses for noncarcinogens incorporate safety factors to account for individual differences in human sensitivity to toxic agents, and are expected to be protective for all segments of the population.

OTHER EVALUATION FACTORS

Cost

The advantages of increased protection of public health and the environment, greater reliability, and faster cleanup must be balanced against impacts on cost. However, remedial actions must always provide protection of public health and the environment, and the primary impact of cost in the decision analysis process should be in selecting the rate at which remediation levels are achieved.

Cost comparisons between alternatives are based on combining both capital and operations and maintenance (O&M) costs into a single value. This present worth cost allows comparisons among remedies that are operated over different lengths of time.

Estimates of uncertainty should be incorporated into cost estimates whenever possible to present a more comprehensive look at expected costs. Potentially significant uncertainties that affect the costs of remedial actions include variations in the discount rate, the duration of the ground water remedial action, and the scope of remedial action. It may be useful to conduct a sensitivity analysis, evaluating the costs of alternatives using a range of values (e.g., vary the discount rate; change the value of hydraulic conductivity of the aquifer; assume that the extent of the actual plume is larger than indicated in the RI). Those ranges should reflect the level of uncertainty for the predicted value (discount rates may range between 4% and 10%; hydraulic conductivities may vary by an order-of-magnitude, etc.).

The impact of uncertainties on costs is likely to vary between alternatives, and this sensitivity to uncertainty may be an important evaluation factor in the decision analysis. If the cost of a remedial action is highly sensitive to an unknown or poorly characterized parameter, that uncertainty may lead the decisionmaker to reject that alternative. Alternatively, that uncertainty may be reduced through pilot studies or additional data collection.

Technical Limits of Aquifer Restoration

One or a combination of hydrogeologic conditions or contaminant properties may limit the effectiveness of any ground water remedial action:

- Low mobility contaminants (e.g., PCBs, PAH compounds)
- Low hydraulic conductivity in the contaminated aquifer
- Complex flow patterns (e.g., flow through fractured rock or through highly channeled limestone units)

These conditions may make it extremely difficult or environmentally disruptive to achieve remediation levels in the performance range. In these cases, the decisionmaker should select an alternative that prevents exposure to contaminated ground water and that approaches the performance range to the maximum extent practical.

Conversely, if the contaminants in ground water are mobile and hydrogeologic conditions are such that high levels of contaminant removal can be achieved without technical difficulty, the decisionmaker should consider a highly protective remedy.

Impacts on Environmental Receptors

If environmental receptors (e.g., aquatic life and/or wildlife) are more sensitive to contaminants in ground water than humans, it may be necessary to establish a remediation level that reduces contaminant concentrations below levels that are protective of human health.

Potential for Spreading of the Contaminant Plume

NOTE: This section may be changed in response to CERCLA reauthorization provisions on Alternate Concentration Limits.

The decisionmaker should emphasize remedial alternatives that limit the spread of contaminants to uncontaminated ground water. In particular, contaminant levels should not be allowed to exceed health-based levels in previously uncontaminated areas. Plume containment measures, such as low-rate pumping to control hydraulic gradients, may be used to minimize continued spreading of the plume. Limited increases in contaminant levels in an uncontaminated area may be acceptable if the increase occurs over a small area, the duration of the period of increased contamination is limited, and, if the plume is discharging to a nearby surface water body, the contaminants have no significant impact on surface water quality. The following factors should be considered in the evaluation of potential surface water impacts:

- The mass loading of contaminants from ground water to surface water

- The ecological value of surface water habitats

- Potential surface water exposure pathways, including direct consumption, food chain, body contact, and volatilization and inhalation

SUMMARY

Evaluation of the cost-effectiveness factors discussed in this section should guide the decisionmaker in the selection of a remedial alternative. It will seldom be the case, however, that after considering these cost-effectiveness factors, one ground water remedial action will clearly emerge as the "right" selection; there are too many complex issues and uncertainties, and the pursuit of a cost-effective remedy involves subjective judgments and trade-offs.

An evaluation of one factor may indicate that there is flexibility to select a remedial alternative that requires a long period of time to reduce contamination in the ground water, while another factor indicates that rapid remediation is important. The decisionmaker may prioritize these various factors based on site-specific circumstances, and select a remedial action based on the "weight of the evidence" developed through the evaluation process.

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Section VI

EVALUATING PERFORMANCE AND MODIFYING REMEDIAL ACTIONS

UNCERTAINTIES IN THE DECISION PROCESS

The scope of the hydrogeologic investigation conducted during an RI may not provide enough data (or the kind of data) on hydrogeologic conditions and contaminant properties to properly design a remedial alternative. Even when a detailed investigation has been performed, the complex behavior of contaminants in ground water combined with the heterogeneity of hydrogeologic systems make accurate predictions of remedial action performance difficult.

Potentially the best tool for developing meaningful and reliable design criteria is to conduct a pilot test in order to establish the effectiveness of a particular remedial alternative or remedial technology. However, ground water remedial alternative pilot studies may increase costs and delay the implementation of a remedial action. The benefits from the pilot testing should, therefore, be balanced against increases in time and costs.

MODIFYING DECISIONS

An option to conducting pilot studies during an RI/FS or the remedial design phase is to conduct performance evaluations of the full-scale remedial action and use that evaluation data to improve performance. This systematic approach allows the decisionmaker some flexibility because a decision can be verified and/or modified during the course of the remedial action to improve cost-effectiveness and ensure protection of public health and the environment.

Figures VI-1A, VI-1B, and VI-1C represent a decrease in contaminant concentration over time for three ground water remedial actions of varying effectiveness. Figure VI-1A shows that the alternative is meeting design expectations, and the desired remediation level is likely to be reached within the anticipated period of time. Figure VI-1B shows that the desired remediation level will be achieved, but the remedial action will have to be operated longer than anticipated. Figure VI-1C shows that the desired remediation level will not be achieved over a very long period of time without modifying the remedial action.

After evaluating the performance of the ground water remedial action, the decisionmaker should consider the following options:

1. Discontinue operation

2. Upgrade the remedial action to achieve the original performance goals

3. Modify the performance goals and continue operation of the remedial action

The performance evaluation program may indicate that the remedial action performance objectives have been met, and the remedy is complete. In other cases, operational results may demonstrate that it is technically impractical to achieve remediation levels within the performance range and an exception to meeting all applicable, relevant, and appropriate Federal requirements may be required. Alternatively, additional information on site conditions or other factors may indicate that remediation levels can be adjusted to less stringent levels and still protect public health and the environment.

These options provide the decisionmaker with flexibility to respond to new information and/or changing conditions over the course of the remedial action. Figure VI-2 illustrates this flexible decision process.

PERFORMANCE MONITORING

This section provides guidelines on how ground water monitoring is used to evaluate performance. It does not provide detailed information on technical aspects of ground water monitoring such as well installation techniques or sampling procedures. The RCRA Ground Water Monitoring Technical Enforcement Guidance Document (Draft, 1985) is one resource for such information.

The monitoring system must be designed to provide information that can be used to evaluate the remedial action. Such information includes the:

- Location and concentration of indicator compounds in the plume
- Rate and direction of contaminant migration
- Changes in contaminant concentrations or distributions over time
- Effects of any modifications to the original remedial action

The key considerations in developing a design for performance monitoring include well locations and the frequency and duration of sampling. General concepts of each topic are presented below.

WELL LOCATIONS

The site-specific nature of ground water contamination problems requires that the number and locations of monitoring wells be suited to site conditions and to the remedial action selected. In general, wells must be located upgradient (to detect contamination from other sources), within the plume (to track the response of plume movement to the remedial action), and downgradient (either to verify anticipated responses or to detect unanticipated plume movement). If a containment system is used, wells or other detection devices should also be located where contaminant releases are most likely to occur.

SAMPLING DURATION AND FREQUENCY

The intervals between sampling events should be shortest (highest sampling frequency) during start-up of the remedial action. In many cases, weekly or semi-weekly sampling intervals are reasonable during the first year of operation.

These first-year data may be used to further characterize the aquifer and to identify locations for additional monitoring.

The recommended long-term frequency for sampling depends in part on the effectiveness of the remedial action, as determined through the ongoing monitoring program. If monitoring shows a steady, predictable decrease in contaminant concentrations in the aquifer, it may be reasonable to reduce the sampling frequency. The determination of long-term sampling frequency should be based on the rate of plume migration and the proximity of downgradient receptors. Quarterly sampling may be reasonable for long-term monitoring at many sites.

Monitoring data provide the basis for determining when performance goals have been met and a remedial action is complete. Operation should continue for a limited period of time after cleanup levels have been achieved. Ongoing monitoring may be appropriate at sites where the previously contaminated aquifer is to be used for drinking water.

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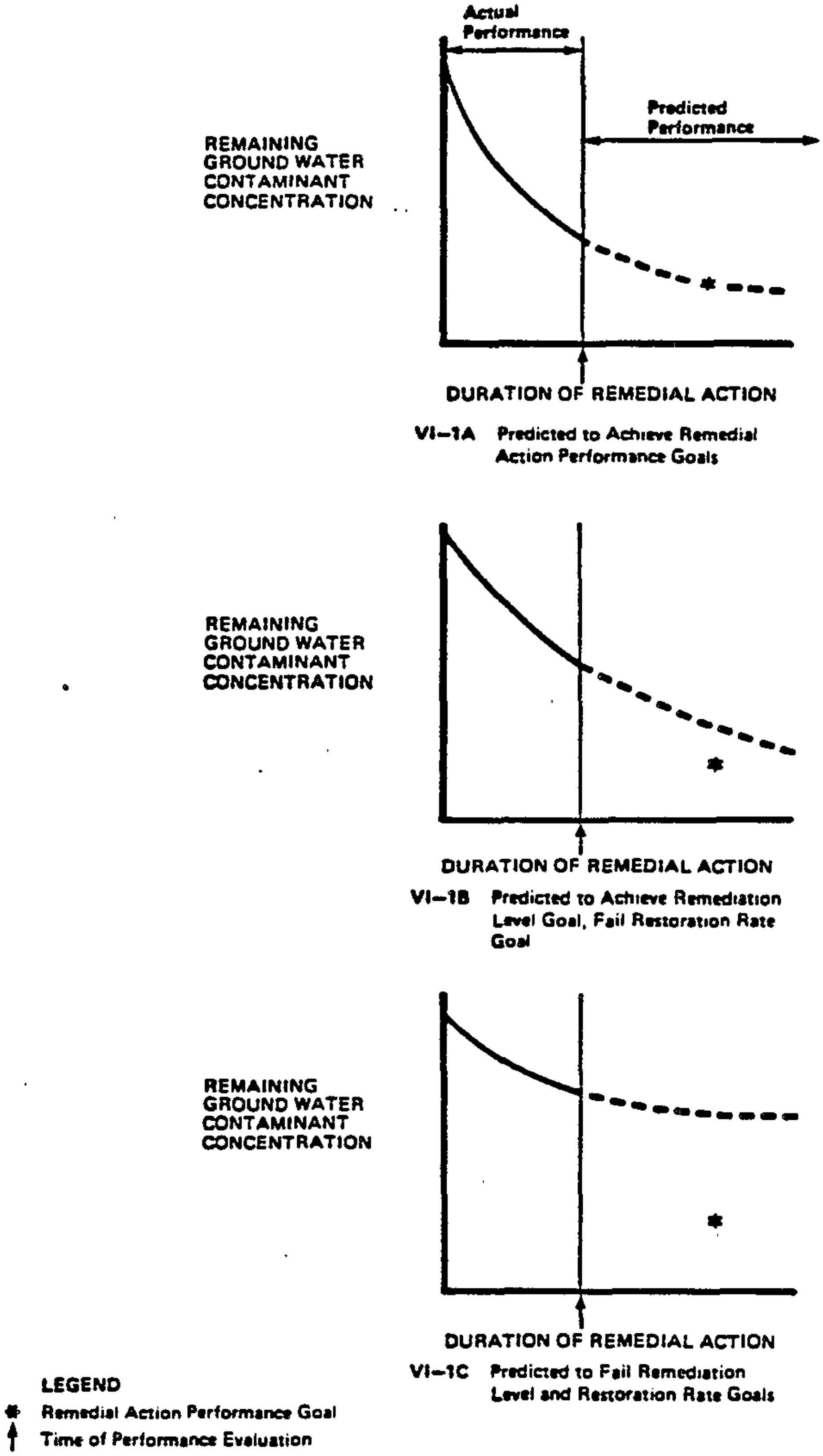

Figure VI-1

PREDICTING REMEDIAL ACTION PERFORMANCE FROM MONITORING DATA

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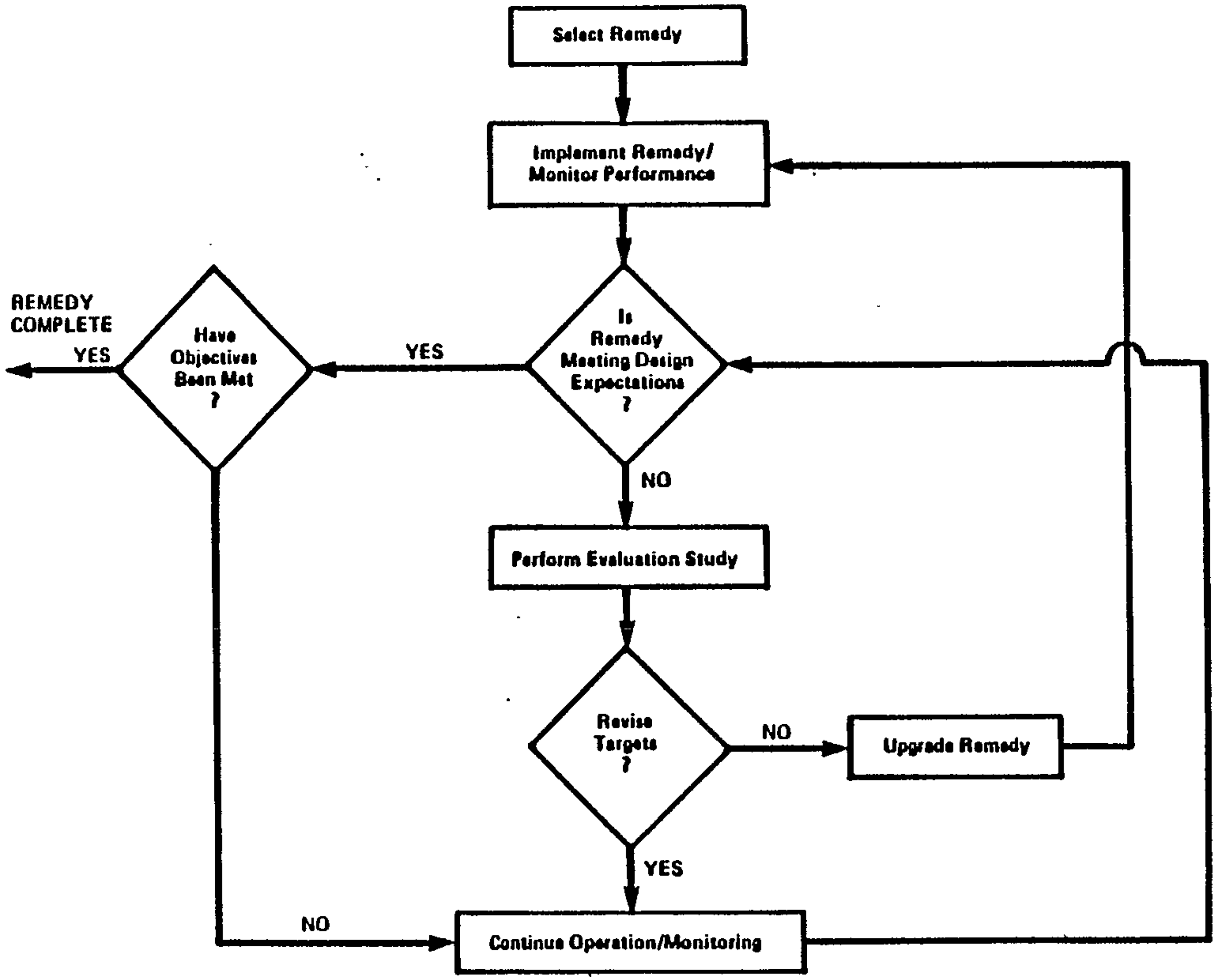

Figure V-2
FLEXIBLE DECIS 'ROCESS FOR

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These first-year data may be used to further characterize the aquifer and to identify locations for additional monitoring.

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Monitoring data provide the basis for determining when performance goals have been met and a remedial action is complete. Operation should continue for a limited period of time after cleanup levels have been achieved. Ongoing monitoring may be appropriate at sites where the previously contaminated aquifer is to be used for drinking water.

WDR153/018

Appendix A

CASE STUDIES

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Appendix A

CASE STUDIES

Case studies are hypothetical scenarios that demonstrate key features of the ground water remedial action decision process. These studies focus on the significance of ground water classification in the evaluation of alternatives, evaluation of other cost-effectiveness factors, as well as the use of the performance range for analyzing ground water remedial alternatives.

These case study scenarios have been simplified relative to many actual Superfund sites. A minimum amount of data is presented, and many real life complicating issues are ignored in order to clarify the decision analysis process. These site scenarios have been selected to demonstrate particular aspects of the decision analysis process:

Site 1: Selection of a highly protective and rapid alternative, (10^{-6} risk level in five years) where the ground water is used for agricultural purposes, but not for drinking water. Potential for future use of ground water, lack of other potential sources, and the effectiveness of institutional controls are key evaluation factors in remedy selection.

Site 2: Selection of a remedy in the "middle" of the performance range where the contaminated aquifer is currently used. Complexity of the hydrogeology and uncertainty about the effectiveness of an aggressive extraction system are key evaluation factors in remedy selection.

Site 3: Selection of a remedy in the "middle" range where the contaminated aquifer is currently used. The presence of an alternate water supply and impacts on surface waters and a downstream water supply are key evaluation factors in remedy selection.

Site 4: Selection of a remedy out of the performance range because of the high cost and technical infeasibility of cleaning up to the risk range in a short period of time. Complex hydrogeology and low contaminant mobility have a major impact on remedy selection.

Site 5: Selection of a remedy based on environmental protection, where there are no hazards to human health.

Site 6: Selection of a natural alternative remedy at a site where the contaminated ground water has Class III characteristics. Effective source control and protection of an underlying aquifer with Class IIA characteristics are key evaluation factors in remedy selection.

At some of the case study sites, a source control action has either been planned or is being implemented. At other sites, several source control alternatives are still under consideration, and this decision will affect the selected ground water remedial alternative.

These case studies are not expected to closely reflect conditions at any actual Superfund sites, where real-life issues will make the selection process more complex. The specifics of any alternatives (i.e., the remedial technologies) are included for the purpose of demonstrating the guidance and should not be interpreted as a preference. Other options may be appropriate based on best engineering judgement and site factors.

WDR177/017

SITE 1--COMMERCIAL LANDFILL--CLASS II GROUND WATER

BACKGROUND

Leachate from an abandoned commercial landfill has entered the ground water, forming a contaminant plume that has migrated about 1,000 feet, covering an area of about 5 acres. The ground water velocity is estimated to be 30 feet per year. The movement of contaminants in ground water is slower because of retardation in the soils and geologic materials, and the plume is migrating at an average rate of about 15 feet per year. Individual contaminants are migrating at different rates based on soil adsorption properties.

Primary contaminants in the ground water include ethylene dibromide (EDB), benzene, carbon tetrachloride, and phenol. The maximum concentrations of these compounds in ground water and associated cancer risks at the site, along with EPA criteria and advisories for protection of human health are given in Table A-1.

A total carcinogenic risk of 3.5×10^{-3} is calculated based on all of the carcinogens present (there are other carcinogens in addition to the primary contaminants) from exposures through ground water consumption and other pathways.

Table A-1
PRIMARY CONTAMINANTS AT SITE 1

Contaminant	Maximum Concentration Detected (ug/l)	AWQC (ug/l)	Drinking Water Health Advisory (ug/l)	Excess Lifetime Cancer Risk	Koc
EBD	1.0	--	(5×10^{-4})	2×10^{-3}	44
Benzene	150	(0.67)	(0.35)	4.3×10^{-4}	83
Carbon Tetrachloride	250	(0.42)	(0.3)	8.3×10^{-4}	110
Phenol	10,000	3,500	--	N/A	14.2

AWQC: EPA Ambient Water Quality Criteria for drinking water only.

--: No criteria or advisory given.

N/A: Compound is not currently listed as a carcinogen.

Values in parentheses associated with the 10^{-6} excess lifetime cancer risk.

Carcinogenic risk calculated based lowest value associated with 10^{-6}.

K_{oc}: Organic carbon partition coefficient.

Reference: Superfund Public Health Evaluation Manual.

WDR177/047

Source control actions planned for the site include removal of containerized liquids, sludges, and approximately one foot of contaminated soils. Liquids and sludges will be incinerated. Soils removed from the site will either be incinerated or treated to reduce contaminant migration potential prior to disposal. The source control action is designed to reduce contaminant concentrations in the leachate below the 10^{-6} cancer risk level, so there will be no continued contaminant loading to the ground water above health-based levels.

The dominant land use around the site is agriculture. The contaminated aquifer is used for irrigation, but no irrigation supply wells have yet been contaminated. If no ground water remedial actions are taken, the plume will migrate to the downgradient irrigation wells, reaching these wells in about 10 years. The contaminants in the irrigation water are not expected to adversely affect crop production, but there is some concern over the potential for future inhalation exposure to agricultural workers in the field. Because the ground water has a current beneficial use (irrigation) it is considered to have Class IIA characteristics.

The closest drinking water supply well in the aquifer is several thousand feet downgradient of the plume. Modeling indicates that contaminant concentrations would be reduced through natural attenuation to levels below the 10^{-6} cancer risk before the plume would reach downgradient users. Geologic formations below this aquifer do not yield enough water to be used extensively for water supply, so development of an alternate water supply is not considered feasible. Plan and profile views of the site are shown in Figure A-1.

If current agricultural land use practices are preserved, exposure levels to contaminants in ground water will be below levels of concern for human health. Within the region, however, conversion of farmland to residential development has been occurring at a rapid pace. Projected changes in land use from agricultural to residential use is expected to lower the overall demand on water supplies, but the quality of the water required will be higher. This potential change in land use increases the potential for exposure in the future. There are no mechanisms in place to restrict ground water use, and institutional controls are not expected to be effective.

RESPONSE OBJECTIVES

Response objectives for ground water include:

- Preventing exposure to currently contaminated ground water;

- o Protecting uncontaminated ground water for current and future use; and
- o Restoring contaminated ground water for future use.

DEVELOPMENT AND EVALUATION OF ALTERNATIVES

Five screened alternatives for ground water remedial action were evaluated in detail in the FS:

1. Pump and treat to achieve a 10^{-6} cancer risk level for carcinogens, or water quality criteria or health advisories for noncarcinogens, within 5 years (point of departure alternative).

2. Pump and treat to achieve a 10^{-6} level and water quality criteria or health advisories within 10 years.

3. Control plume migration using gradient control wells until a 10^{-4} cancer risk level is achieved.

4. Control plume migration using gradient control wells until a 10^{-6} cancer risk level is achieved.

5. Allow the plume to migrate to the irrigation wells (over an estimated 15 year period), then pump and treat the ground water using the irrigation wells.

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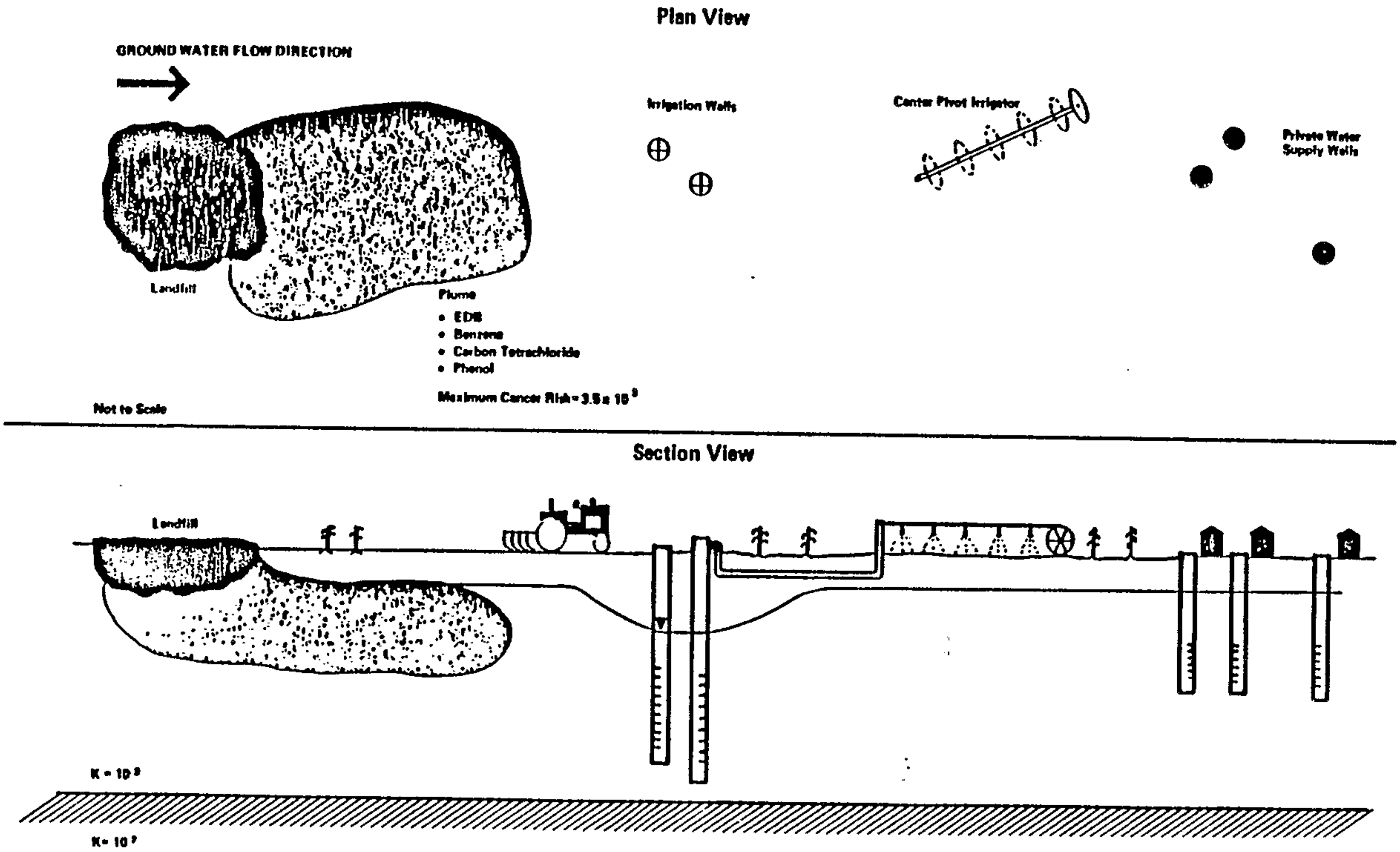

Figure A - 1

CASE STUDY 1
SITE LAYOUT

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5. Natural attenuation to the 10^{-4} risk level.

6. Natural attenuation to the 10^{-6} level.

The point of departure alternative and the two natural attenuation alternatives should be evaluated in the FS at most sites. The other three alternatives fall within the recommended performance range for ground water remedial actions at sites where ground waters have Class I or Class II characteristics, and are intermediate between the point of departure alternative and the two natural attenuation alternatives.

Point of Departure Alternative

In order to meet the performance goals of the point of departure alternative, the proposed remedial action consists of four extraction wells followed by carbon adsorption to remove organic compounds. Treated ground water is stored in an impoundment and is available for use as a supplemental irrigation water source. The present worth cost of this alternative is $5 million.

Other Alternatives in the Performance Range

A second pump and treat alternative consists of two extraction wells followed by carbon adsorption. The 10^{-6}

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cancer risk level and standards and criteria are achieved in 10 years. The present worth cost of this alternative is estimated at $3.5 million.

The third alternative in the performance range consists of a series of well points pumping at rates that are sufficient to maintain an inward gradient, therefore preventing further plume migration. Discharge from these low rate wells is collected in a surface impoundment. The impoundment is aerated to increase volatilization. The downgradient irrigation wells are shut down during the remedial action to reduce the pumping rates needed to prevent further migration of the plume. Modeling indicates that 10 years are required to reduce contaminants to the 10^{-4} cancer risk level. The present worth cost of this alternative is estimated at $800,000. The fourth alternative involves extending the operation of the gradient control wells until contaminant levels are reduced to the 10^{-6} level. Modeling indicates that 20 years are required. The present worth cost is estimated at $1.5 million.

A fifth alternative consists of allowing the plume to continue to migrate toward the irrigation wells, then using these wells to pump contaminated ground water on a continuous basis, treating the contaminated ground water through carbon adsorption. Treated water is either used for irrigation or stored in an impoundment. About 10 years are required for the plume to reach the irrigation wells, followed by 10 years of accelerated pumping and treatment to meet the 10^{-6} cancer risk level. The present worth cost of this alternative is $1 million.

Natural Attenuation Alternatives

An evaluation of the time required for natural attenuation to reduce contaminant concentrations to both the 10^{-4} and 10^{-6} levels, and the associated impacts on human health and the environment should be conducted at most sites. Natural attenuation alternatives involve no active restoration measures, but may include monitoring, institutional controls, and alternate water supply as part of the alternative.

At Site 1, natural attenuation is expected to reduce contaminant levels to the 10^{-4} cancer risk level in 30 years, and therefore falls within the performance range. The 10^{-6} cancer risk level is expected to be reached in 60 years. Contaminant concentration diminish to the 10^{-6} cancer risk level before reaching any of the water supply wells that are currently in use. The present worth costs for the 10^{-4} and 10^{-6} natural attenuation alternatives are $300,000 and $450,000 respectively. These costs are primarily for monitoring.

All of the alternatives fall within the performance range for Class I and II ground waters (see Figure A-2). Alternatives 5, 6, and 7 allow for continued contaminant migration and enlargement of the plume before cleanup targets are achieved. Therefore, institutional controls restricting use of ground water are applied over an expanded area. In general, remedial actions that allow the contaminant plume to continue to spread are not favored.

In the cost-effectiveness evaluation process, the additional costs associated with speeding restoration rates are balanced against the risk of future exposures if restrictions on ground water use are not effective. As discussed in the site background information, the effectiveness of institutional controls at Site 1 is uncertain.

A summary of site conditions and alternative evaluation factors is presented Table A-2. A summary of the alternatives is presented in Table A-3.

The contaminated ground water has a current beneficial use as an irrigation supply, and thus has characteristics of Class IIA ground water. It is not, however, a current source of drinking water, and from the perspective of

SITE 1 - EXPECTED PERFORMANCE OF GROUND WATER REMEDIAL ALTERNATIVES

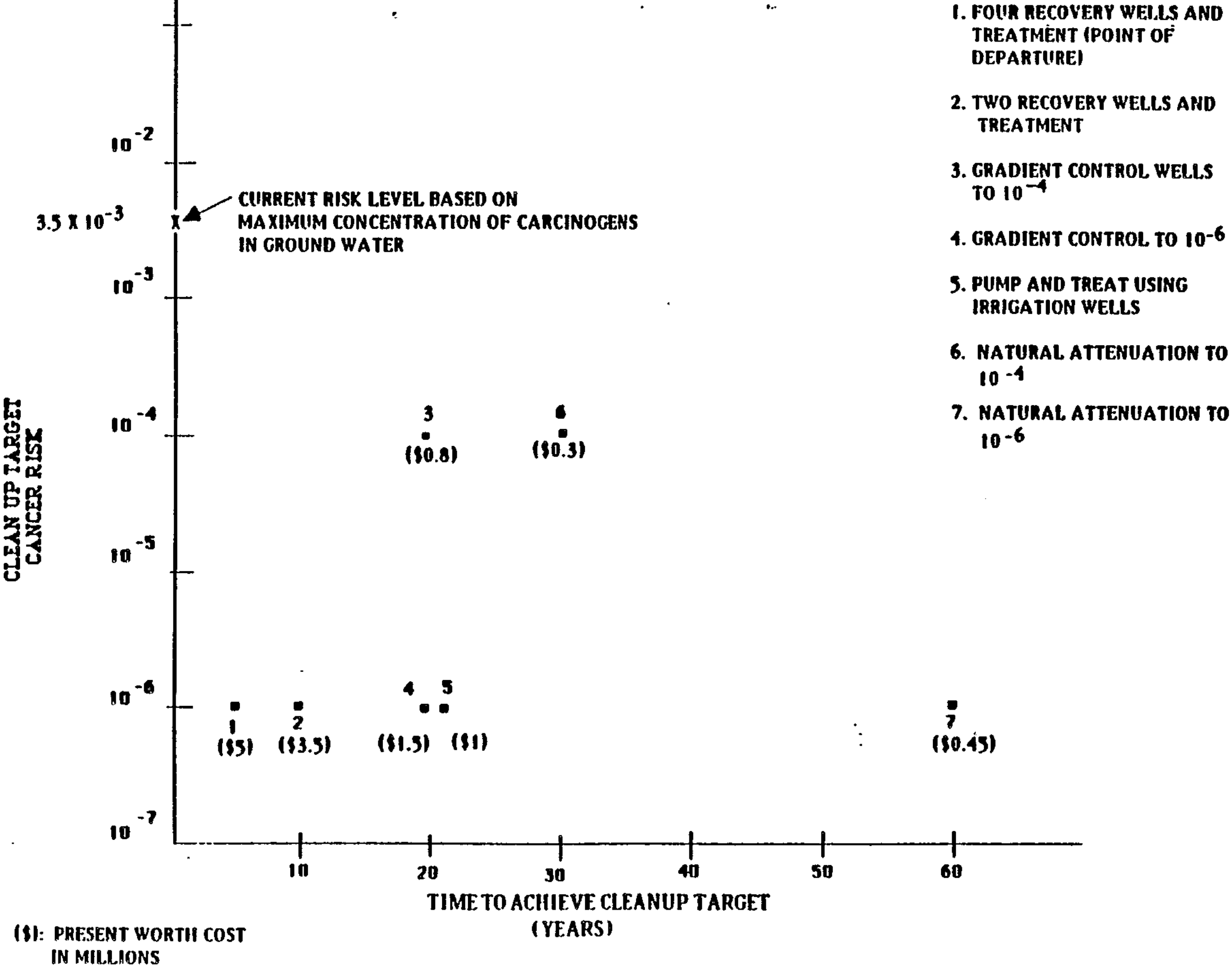

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Table A-2
SITE CHARACTERISTICS AND DECISION ISSUES - SITE 1

<u>SITE DESCRIPTION</u>

- Commercial landfill, 5 acres

- Source Control: Contaminants in leachate below 10^{-6} risk.

- Hydrogeology: Unconsolidated deposits, ground water velocity 30 ft/year.

- Primary Contaminants: EDB, benzene, carbon tetrachloride, phenol.

- Plume Characteristics: Migrated 1,000 feet, migration rate about 15 feet per year.

- Risks: Maximum risk considering all pathways and all contaminants is 3.5×10^{-3}.

- Other Exposure Pathways: Concern over inhalation pathway for farm workers.

<u>GROUND WATER USE AND AVAILABILITY:</u>

- Current Use: Agricultural; requires high volume; current quality acceptable.

- Projected Use: Residential; requires lower volume, higher quality.

- Sources: No viable water supply sources other than contaminated aquifer.

- Classification of Contaminated Aquifer: Class IIA based on current use as an irrigation supply. More comparable to Class IIB from a drinking water perspective.

<u>ALTERNATE WATER SUPPLY</u>

Not readily available.

<u>ENVIRONMENTAL PROTECTION</u>

- No impacts expected on crops.

- No other environmental receptors.

INSTITUTIONAL CONTROLS

Not expected to be effective over the period of transition from agricultural to residential land use.

REMEDIAL ALTERNATIVES

- Technical Feasibility: All alternatives feasible.
- Remediation Levels/Costs/Rate of Restoration: See Table A-3.

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Table A-3

SITE 1 SUMMARY OF GROUND WATER REMEDIAL ALTERNATIVES

Alternative	Remediation Target	Duration of Remedial Action	Present Worth Cost	Comments
1. Pump at high rate; treat with carbon adsorption	10^{-6}	5 years	$5 million	Point of departure; recommended alternative
2. Pump at lower rate; carbon adsorption	10^{-6}	10 years	$3.5 million	
3. Hydraulic gradient control wells; aerated lagoon; shut down irrigation wells	10^{-4}	10 years	$800,000	
4. Hydraulic gradient control wells; aerated lagoon; shut down irrigation wells	10^{-6}	20 years	$1.5 million	
5. Natural migration followed by pump and treat using irrigation wells	10^{-6}	20 years	$1 million	Presumes irrigation wells will remain in use; allows further migration of the plume.
6. Natural attenuation to 10^{-4} level; shut down irrigation wells	10^{-4}	30 years	$300,000	Long-term institutional controls required over large area; increased potential for exposure to contaminated (>10^{-4} risk) ground water
7. Natural attenuation to 10^{-6} level; shutdown irrigation wells	10^{-6}	60 years	$450,000	As above; longer action but reduced potential for future exposure.

protecting human health and the environment, the ground water is more comparable to Class IIB.

The emphasis on rapid restoration is diminished for Class IIB aquifers, indicating that a slower and less costly remedy may be cost effective. However, because of the projected changes in future land use, doubts about the effectiveness of institutional controls, and the marginal characteristics of other potential water supplies, rapid restoration is considered a priority at this site, and the point of departure remedy (Alternative 1) is recommended.

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SITE 2--ABANDONED DUMP--CLASS IIA GROUND WATER

BACKGROUND

Site 2 is an abandoned hazardous waste storage and disposal facility. The facility covers about 2.5 acres. Liquid organic wastes have contaminated soils and ground water through spills, leaking drums, and infiltration from a hazardous waste lagoon. Drums and liquids from the lagoon have been removed from the site. Highly contaminated sludges and soil "hot spots" remain onsite. RI results indicate that contaminants continue to migrate from the dumpsite to the ground water. The ground water contaminant plume currently extends over about 50 acres.

Primary contaminants in the ground water are TCE, 1,2-dichloroethylene (1,2-DCE), ethylbenzene, and vinyl chloride. The excess lifetime cancer risk associated with consumption of ground water at the maximum concentrations of these and other carcinogens detected at the site is 1×10^{-2}. TCE is transformed to 1,2-DCE, which is then transformed to vinyl chloride through anaerobic biodegradation processes. Ground water data collected over time confirms TCE is degrading to 1,2-DCE and vinyl chloride. Vinyl chloride is a more potent carcinogen than the parent compound. Fate and transport modeling incorporating biodegradation rate constants for TCE and 1,2-DCE indicate that the cancer risk in ground water is expected to increase over time to 2×10^{-2}. Table A-4 is a summary of primary contaminant concentrations, risks, and mobility characteristics, along with health based criteria.

The surficial aquifer at the site consists of stratified sands, silts, and clays. These unconsolidated deposits vary in thickness from 30 to 40 feet, and overlie a fractured bedrock zone that varies between 15 and 25 feet in thickness. The highest contaminant levels are generally found in the fractured bedrock. Both the unconsolidated deposits and the fracture zone are used for a drinking water supply. A deeper, uncontaminated aquifer is present in the region. The contaminated aquifer is not a sole source and therefore is considered to have Class IIA characteristics.

Ground water beneath the site discharges to a river about one-half mile downgradient of the site. Current land use in the area is low-density residential, with approximately 100 homes with individual wells between the site and the river. The contaminant plume has reached ten of the homes nearest the site. An alternate water supply well was installed about 1/3 mile upgradient of the site, and connections were made to these ten homes. These wells near the site have been abandoned and plugged. A diagram of the site is shown in Figure A-3.

Table A-4
PRIMARY CONTAMINANTS AT SITE 2

Contaminant	Maximum Concentration Detected (ug/l)	AWQC (ug/l)	Drinking Water Health Advisory (ug/l)	Excess Lifetime Cancer Risk	Koc
Trichloroethylene	2,700	(2.8)	(2.8)	$1x10^{-3}$	126
1,2-Dichloroethylene	400	--	--	N/A	59
Vinyl Chloride	135	2.0	0.015	$9x10^{-3}$	57
Ethylbenzene	100	2400	3400	N/A	1100

AWQC: EPA Ambient Water Quality Criteria for drinking water only.

--: No criteria or advisory given.

N/A: Compound is not currently listed as a carcinogen.

Values in parentheses associated with the 10^{-6} excess lifetime cancer risk.

Carcinogenic risk calculated based lowest value associated with 10^{-6}.

K_{oc}: Organic carbon partition coefficient.

Reference: Superfund Public Health Evaluation Manual.

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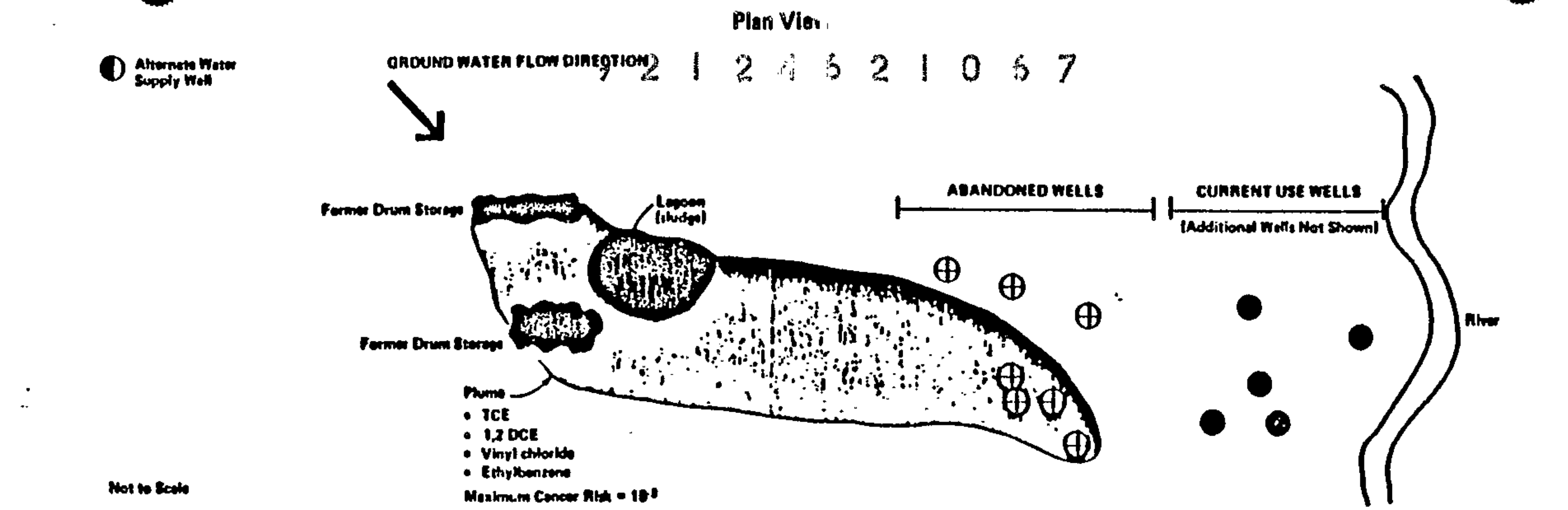

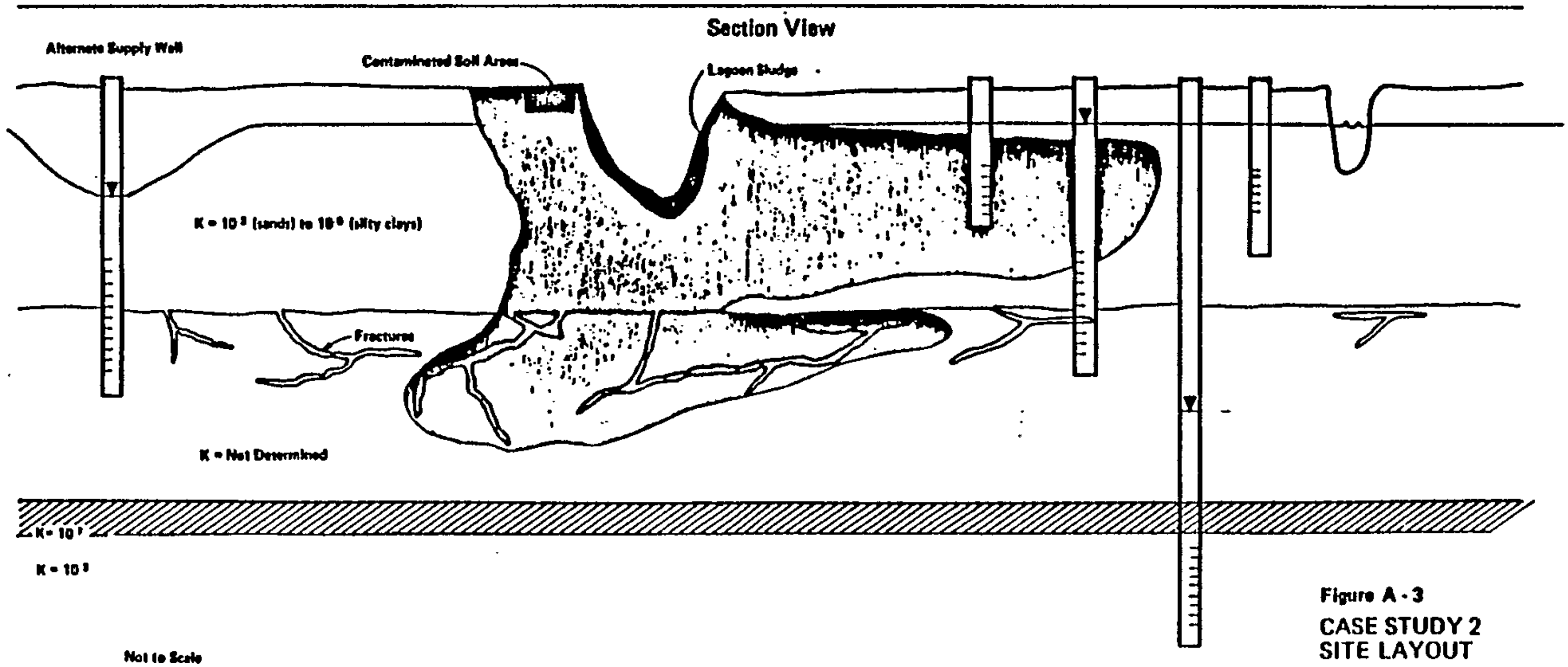

Figure A - 3
CASE STUDY 2
SITE LAYOUT

Water use is not expected to increase significantly in the future. However, the existing alternate water supply does not have the capacity to provide for all of the current homeowners between the site and the river. Institutional mechanisms are currently in place to restrict drilling of any new wells in the area. These controls are expected to be effective.

RESPONSE OBJECTIVES

Response objectives for remedial actions at this site include:

- o Preventing exposure to contaminated ground water;
- o Protecting uncontaminated ground water for current and future use;
- o Restoring contaminated ground water for future use;
- o Preventing the discharge of harmful levels of contaminants from the ground water to the surface water;
- o Preventing direct contact with contaminated soils; and

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- Reducing contaminant migration from the source area to the ground water.

DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES

Five screened alternatives for ground water remedial action were evaluated in detail:

1. Pump and treat to achieve a 10^{-6} cancer risk level in ground water in 5 years or less (point of departure alternative).

2. Pump and treat to achieve a 10^{-5} risk level in ground water in 10 years.

3. Pump and treat to achieve a 10^{-4} risk level in 10 years.

4. Maintain gradient control (containment) until a 10^{-4} risk level is achieved.

5. Maintain gradient control (containment) until a 10^{-6} risk level.

6. Natural attenuation to a 10^{-4} risk level.

7. Natural attenuation to a 10^{-6} risk level.

The point of departure alternative and the two containment (or natural attenuation) alternatives should be evaluated at most sites. Containment alternatives are favored over natural attenuation at this site because the latter would result in significant spreading of the contaminant plume before discharging to the river about one half mile down-gradient. A limited number of other alternatives in the ground water remedial action performance range should also be evaluated.

The evaluation of alternatives is complicated by the fact that the source control operable unit has not yet been selected. The effectiveness of the source control action will have a significant impact on the cleanup level achieved, and the rate of restoration of the ground water remedial alternatives. Therefore, the source control alternative should be evaluated in light of the performance goals established for ground water remediation. To simplify the evaluation of ground water alternatives, it is assumed for the purposes of this case study that each of the ground water alternatives is combined with a source control action that reduces contaminant concentrations in leachate from the site to the 10^{-6} cancer risk level. If source control measures are less effective, the actual ground water restoration periods will be longer than the estimates presented.

Point of Departure Alternative

Because of the complex flow patterns in the aquifer, a network of 10 wells completed in both the unconsolidated deposits and in the fractured bedrock aquifer are needed to meet the performance goal of reducing contaminant concentrations to the 10^{-6} cancer risk level within 5 years. Contaminated ground water is treated through air stripping followed by reinjection to the aquifer. The reinjection system is expected to accelerate the rate of contaminant removal. However, RI data on the hydraulic properties of the fractured bedrock zone are incomplete, and the effectiveness of the extraction/reinjection system is uncertain. Emissions from the air stripping system will be treated to remove volatile organic compounds.

Because of the high cancer potency of vinyl chloride, special laboratory methods may be required in order to achieve detection limits at the 10^{-6} risk level (0.015 ug/l for vinyl chloride). The present worth cost of this alternative is estimated at $10 million.

Other Alternatives in the Performance Range

A second pump and treat alternative is designed to achieve a 10^{-5} risk level for carcinogens in ground water within a 10 year period. This alternative consists of five extraction wells--three in the fractured bedrock aquifer and two in the unconsolidated deposits--followed by air stripping and reinjection. Following the 10 year operating period, natural attenuation is expected to reduce carcinogen concentrations to a 10^{-6} level within 30 years. The present worth cost of this alternative is estimated at $6 million.

The third pump and treat alternative is designed to achieve a 10^{-4} risk level for carcinogens in ground water within a 10 year period. Two extraction wells are used and treated ground water is discharged to the river rather than reinjected in the aquifer. Natural attenuation following the operating period is expected to reduce contaminant levels in the aquifer to the 10^{-6} level in 50 years. The present worth cost of this alternative is estimated at $4 million.

<u>Gradient Control (Containment) Alternatives</u>

Gradient control alternatives are evaluated over two time periods; the time to achieve a 10^{-4} cancer risk level and the time to achieve a 10^{-6} cancer risk level in the ground water.

The components of these alternatives include low rate pumping to minimize plume migration, ground water monitoring, maintenance of institutional controls, and provision of an alternate water supply.

Gradient control is expected to reduce contaminant levels to the 10^{-4} level in 30 years, and to the 10^{-6} level in 60 years. The present worth costs for these alternatives are \$2.5 million (10^{-4} level) and \$3.0 million (10^{-6} level).

Natural Attenuation Alternatives

Natural attenuation alternatives are evaluated over time periods required to achieve a 10^{-4} and a 10^{-6} cancer risk level. Components of these alternatives are similar to the containment alternatives, except that no gradient control wells are used.

Although natural attenuation mechanisms will gradually lead to a drop in the maximum contaminant concentrations in the plume, the plume will cover a larger area, and additional homes will be connected to the alternate water supply system. The existing upgradient alternate supply well does not produce enough water to meet the needs of all of the homes between the site and the river, so the alternate water supply capacity will be expanded.

The FS included a detailed evaluation of surface water impacts resulting from the discharge of contaminated ground water to the river. Dilution in the river is sufficient such that contaminant loading from the ground water if not expected to result in a measurable increase in the river.

Natural attenuation is expected to reduce contaminant levels to the 10^{-4} level within 50 years, and to the 10^{-6} level within 100 years. The present worth costs for these alternatives are $1 million ($10^{-4}$ level) and $1.4 million ($10^{-6}$ level).

DECISION SUMMARY

A summary of site conditions and alternative evaluation factors is presented in Table A-5. A summary of alternatives is given in Table A-6. Figure A-4 shows each of the alternatives in the context of the ground water remedial action performance range.

The remedial action performance objectives for Class IIA ground water are to reduce contaminants to levels that are safe for human consumption, and to achieve these levels within a reasonable period of time. The gradient control and natural attenuation alternatives depend on an alternate water supply and the long-term effectiveness of institutional controls for protection of public health, and are not consistent with these objectives.

The point of departure alternative (Alternative 1) is the most protective of the remedies presented, and is consistent with the objective of rapid restoration for Class IIA ground water. However, there is significant uncertainty over the

Table A-5
SITE CHARACTERISTICS AND DECISION ISSUES

SITE DESCRIPTION:

- Abandoned dump, 2.5 acres

- Source Control: No alternative selected. Effectiveness of source an important evaluation factor

- Hyrdogeology: Stratified sands, silts, and clays, 30 to 40 feet thick, over fractured bedrock.

- Primary Contaminants: TCE, 1,2-dichloroethylene, ethylbenzene, vinyl chloride

- Plume Characteristics: Covers 50 acres, migration rate about 10 feet per year. TCE degrading to 1,2-dichloroethylene and vinyl chloride

- Risks: Ground water risk estimated at 1×10^{-2}. Transformation of TCE to vinyl chloride expected to increase risks.

- Other Exposure Pathways: No pathways other than ground water. Concern over intermedia transfer of contaminants to air during treatment.

GROUND WATER USE AND AVAILABILITY:

- Current Use: Drinking water for 90 private residences.

- Projected Use: No increase in demand.

- Sources: Deeper aquifer available for use.

- Classification of Contaminated Aquifer: Class IIA characteristics

ALTERNATE WATER SUPPLY:

Alternate water supply currently serves 10 homes. Feasible to develop a larger alternate water supply system.

ENVIRONMENTAL PROTECTION:

No impacts on surface water or other environmental receptors.

INSTITUTIONAL CONTROLS:

Expected to be effective.

REMEDIAL ALTERNATIVES:

- Technical Feasibility: Effectiveness of ground water extraction system uncertain.
- Remediation Levels/Costs/Rate of Restoration: See Table A-6.

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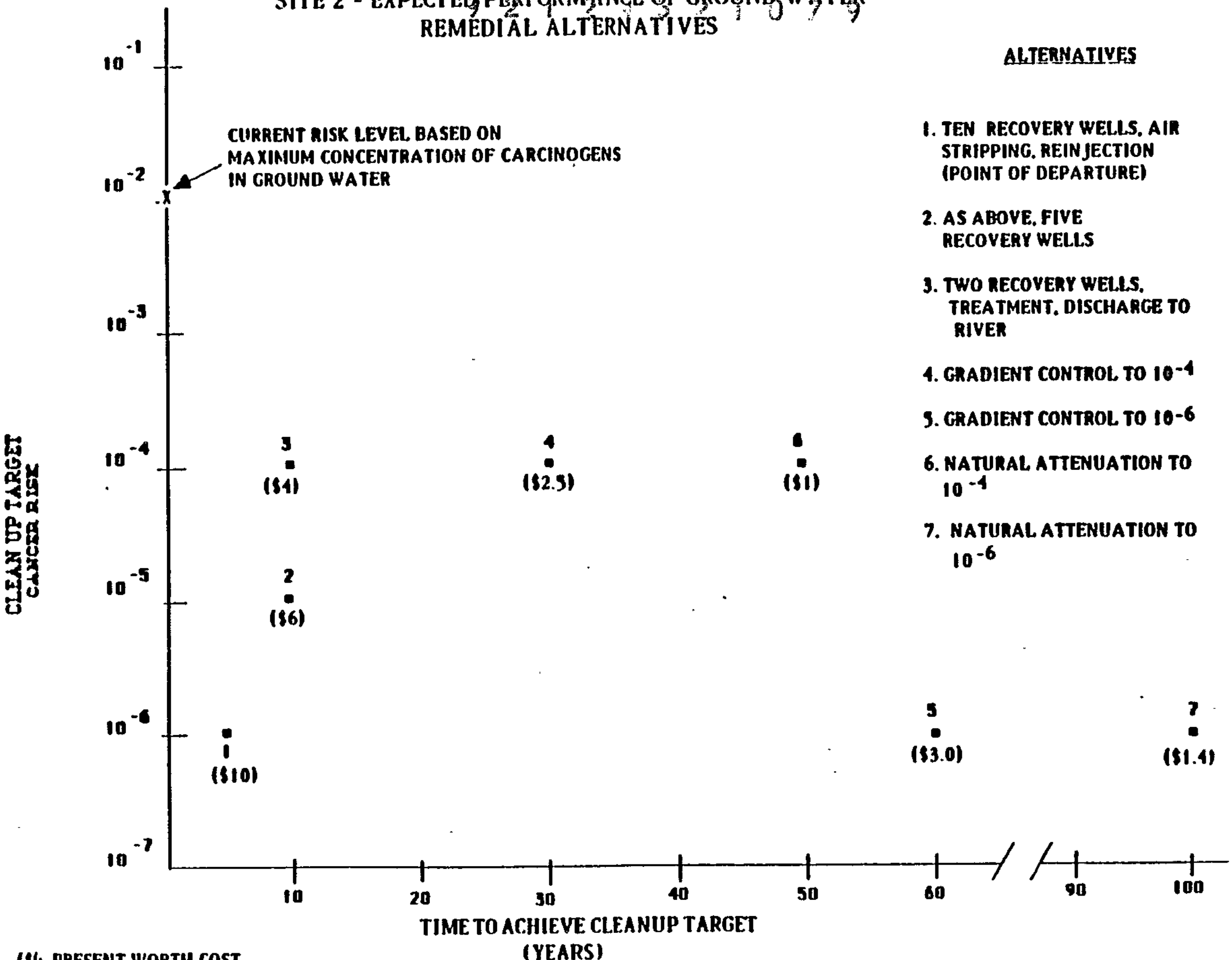
Table 6-6

SITE 2 - SUMMARY OF GROUNDWATER REMEDIAL ALTERNATIVES

Alternative	Remediation Target	Duration of Remedial Action	Present Worth Cost	Comments
1. Ten extraction wells; air stripping; reinjection to the aquifer.	10^{-6}	5 years	\$10 million	Point of departure alternatives, concern over laboratory analysis at 10^{-6} level.
2. Five extraction wells; air stripping, reinjection to the aquifer.	10^{-5}	10 years	\$6 million	Recommended remedial action. Greater feasibility than the point of departure alternative.
3. Two extraction wells, air stripping, discharge to the river.	10^{-4}	10 years	\$4 million	
4. Gradient control until 10^{-4} cancer risk level is achieved.	10^{-4}	30 years	\$2.5 million	Long-term monitoring and institutional controls required.
5. Gradient control until 10^{-6} cancer risk level is achieved.	10^{-6}	60 years	\$3.0 million	As above; longer action, but reduced potential for future exposure.
6. Natural attenuation to 10^{-4} cancer risk level	10^{-4}	50 years	\$1 million	Long-term monitoring and institutional controls required; expansion of alternate water supply system.
7. Natural attenuation to 10^{-6} level	10^{-6}	100 years	\$1.4 million	As above; longer action, but reduced potential for future exposure.

FIGURE A-4
SITE 2 - EXPECTED PERFORMANCE OF GROUND WATER
REMEDIAL ALTERNATIVES



($): PRESENT WORTH COST
IN MILLIONS

effectiveness of the ground water extraction component of the alternative, and complications associated with the sensitivity of laboratory analysis methods for vinyl chloride.

The other two pump and treat alternatives are both considered technically feasible, and both fall within the ground water remedial action performance range. Considering the performance objectives of rapid restoration to protective levels for Class IIA aquifers, the more aggressive and protective alternative (10^{-5} risk level in 10 years) is recommended.

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SITE 3--ABANDONED LAGOON--CLASS II GROUND WATER WITH ALTERNATE WATER SUPPLY

BACKGROUND

Site 3 is an abandoned five-acre lagoon that was used for the disposal of chemical production wastes for over 30 years. Wastes disposed at the site included halogenated and nonhalogenated organics, other industrial solvents, fly ash and bottom ash, and trash. Sludge, sludge/soil mixtures, solids, and liquids have been removed from the lagoon. Residual levels of contamination are low enough to be safe for direct contact and will no longer be a source for ground water contamination.

The contaminant plume covers about 60 acres. Primary contaminants include chloroform, ethylbenzene, and methyl ethyl ketone. The excess lifetime cancer risk based on maximum concentrations of contaminants in ground water is 4×10^{-2}. Contamination levels, health criteria, and contaminant mobility characteristics are given in Table A-7. The contaminated ground water discharges to a river one-half mile downgradient. The plume is migrating at a rate of about 25 feet per year. The river is fished by local residents, and there is an intake for a separate community's

Table A-7
PRIMARY CONTAMINANTS AT SITE 3

Contaminant	Maximum Concentration Detected (ug/l)	AWQC (ug/l)	Drinking Water Health Advisory (ug/l)	Excess Lifetime Cancer Risk	Koc
Chloroform	75	(0.19)	--	$4x10^{-2}$	31
Ethylbenzene	5000	2400	3400	N/A	1100
Methyl Ethyl Ketone	1500	--	860	N/A	4.5

AWQC: EPA Ambient Water Quality Criteria for drinking water only.

--: No criteria or advisory given.

N/A: Compound is not currently listed as a carcinogen.

Values in parentheses associated with the 10^{-6} excess lifetime cancer risk.

Carcinogenic risk calculated based lowest value associated with 10^{-6}.

K_{oc}: Organic carbon partition coefficient.

Reference: Superfund Public Health Evaluation Manual.

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water supply one mile downstream of the ground water discharge zone. Low levels of contamination have been measured in ground water samples taken from the opposite side of the river. A conceptual layout of the site and plume is given in Figure A-5.

Analysis of this downstream water supply indicates that chlorination (for disinfection of drinking water) results in the formation of low concentrations of trihalomethanes, and the "ambient" cancer risk level of the downstream community's water supply is estimated at 5×10^{-7}.

Land use around the site is a combination of commercial and moderately dense residential development. The contaminated aquifer had been used as the primary water supply for the area until the mid-1970s, at which time a municipal system was extended to the area. The municipal drinking water system that has been extended to the area is considered to be a reliable long-term supply. A few businesses and home-owners continued to use private wells for a number of years. When the site was placed on the NPL list, the ground water contaminantion problem received considerable public attention, and use of those remaining private wells was discontinued by order of the health department. The removal of wells in response to ground water contamination has raised questions over whether the contaminated aquifer has

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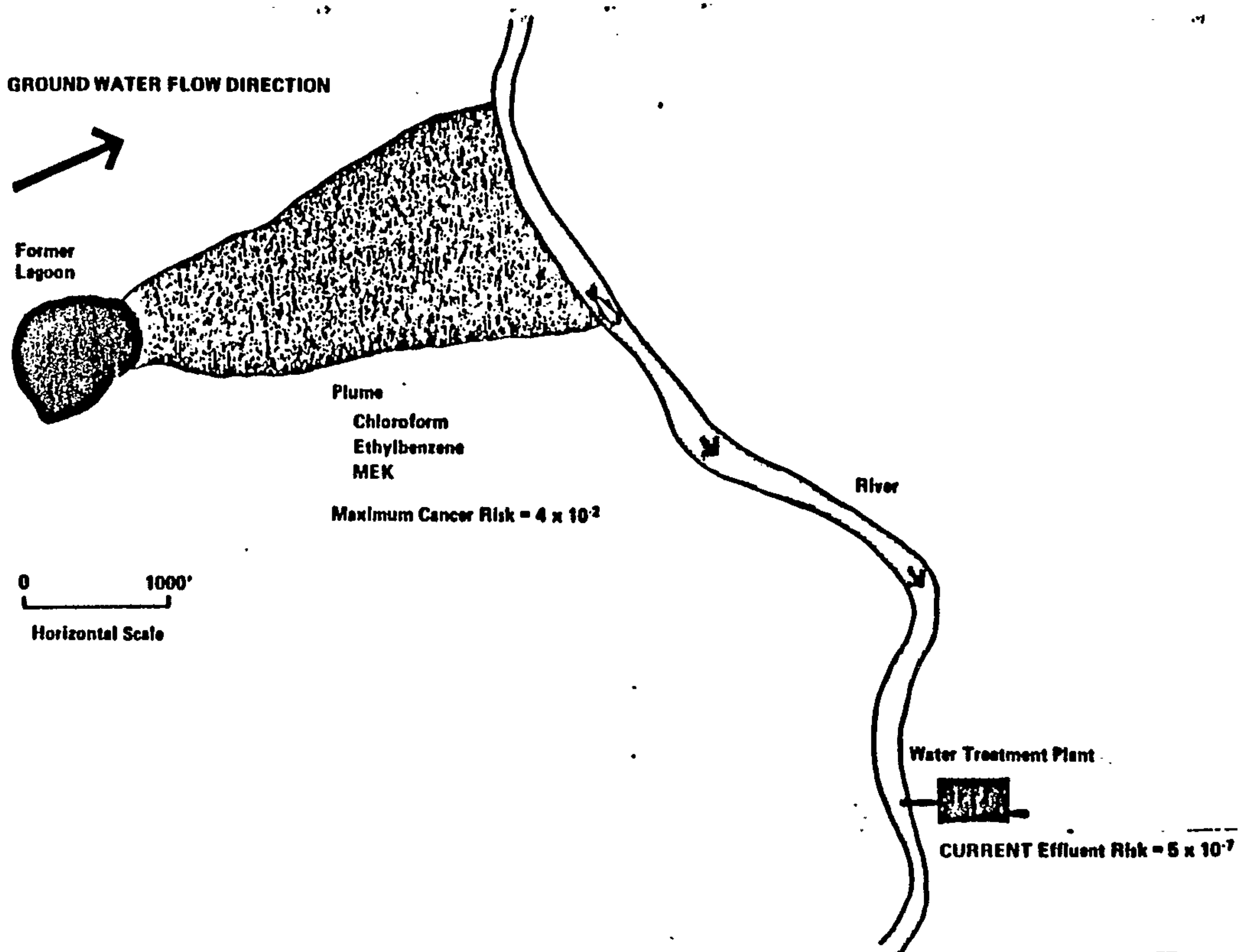

Figure A-5
CASE STUDY 3
SITE LAYOUT

Class IIA (current use) or Class IIB (potential use) characteristics.

Land use projections expect limited growth in the area, and the municipal water supply is adequate to meet long-term demands.

RESPONSE OBJECTIVES

Response objectives for the site include:

- o Preventing exposure to currently contaminated ground water;
- o Protecting uncontaminated ground water for current and future use;
- o Restoring contaminated ground water for future use; and
- o Protecting surface water quality for the downstream drinking water supply and for fishing.

The municipal water system which serves the contaminated area provides a safe alternative water supply, and will be combined with institutional controls restricting ground water use to prevent exposure to currently contaminated

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ground water. The existence of the municipal water supply is expected to increase the reliability of institutional controls restricting ground water use in the area of the plume.

The second response objective, protecting uncontaminated ground water, involves minimizing further migration of the contaminant plume within the shallow aquifer. Deep aquifers are protected by the presence of a thick, continuous, and very low permeability clay layer below the contaminated aquifer.

The level of cleanup in the contaminated aquifer, and the rate at which the ground water is cleaned up, should be evaluated in light of the fact that there are no current users of the aquifer. However, the only "barriers" to the use of, and exposure to, contaminated ground water are institutional controls, and the reliability of those controls must be carefully and realistically considered.

Ground water contaminant fate and transport models, coupled with flow models for the river and estimates of bioaccumulation rates, indicate that contaminant levels in fish will result in a cancer risk level of 10^{-8} through food chain uptake.

Cancer risk levels in the downstream drinking water supply serving the neighboring community are expected to exceed the 10^{-6} risk level during the interval when the most highly contaminated part of the plume is discharging to the river. Both contaminants from the site and trihalomethanes that are currently in the water supply contribute to the total risk. This 10^{-6} risk level is calculated based on a lifetime ingestion of two liters of water for 70 years. The period of time over which the risk level in the downstream drinking water is expected to exceed the 10^{-6} level is 15 years, so the risk determinations may be overly conservative.

DEVELOPMENT AND EVALUATION OF ALTERNATIVES

Five screened alternatives were evaluated for ground water. These alternatives include:

1. A pump and treat alternative that restores ground water to the 10^{-6} level in five years or less (point of departure alternative).

2. Pump and treat to reduce ground water contaminant levels to a 10^{-4} cancer risk level in 10 years.

3. Gradient control wells to prevent further migration of the most highly contaminated part of the plume. Gradient control wells will be

operated for 20 years, at which time contaminant levels are expected to be reduced to a 10^{-4} cancer risk level.

4. Natural attenuation to the 10^{-4} cancer risk level.

5. Natural attenuation to the 10^{-6} cancer risk level.

<u>Point of Departure Alternative</u>

The point of departure alternative consists of six extraction wells followed by treatment through carbon adsorption and discharge to the river. The point of departure alternative rapidly restores contaminated ground water to safe levels, consistent with the ground water remedial actions goals for Class I and Class II aquifers. The present worth cost of the alternative is $7 million.

<u>Other Alternatives in the Performance Range</u>

The second pump and treat alternative consists of one extraction well located to capture the most highly contaminated portion of the plume. Ground water will be treated by carbon adsorption and discharged to the river. The extraction and treatment system will be operated for approximately 15 years, at which time contaminant levels are expected to be reduced to a 10^{-5} level.

Approximately half of the volume of the plume will not be pumped and will continue to flow into the river. The mass of contaminants in this less contaminated portion of the plume represents about one-tenth of the total mass of contaminants currently in the ground water, and is not expected to have any measurable effect on the downstream water supply system. By eliminating zones of high ground water contamination, this alternative also reduces potential health impacts from deliberate or unintentional violations of institutional controls restricting ground water use. The present worth cost of this alternative is estimated at $4.5 million.

A third alternative has the same components as the second pump and treat alternative, with the remediation level objective set at the 10^{-4} cancer risk level. This alternative is expected to reduce contaminant levels within a reasonable period of time (10 years), and institutional controls at this site are expected to be effective through that period. While future exposures to less contaminated ground water remains a concern, the potential health impacts from such exposures are reduced. The present worth cost of the alternative is estimated at $3 million.

The fourth alternative (gradient control) prevents highly contaminated ground water from discharging to the river. Contaminant levels are reduced to the 10^{-4} level within

20 years. Natural attenuation is expected to reduce contaminant concentrations to the 10^{-6} level in 40 years. The present worth cost of the gradient control alternative is \$1.5 million.

Natural Attenuation Alternatives

Natural attenuation alternatives with 10^{-4} and 10^{-6} cancer risk targets were evaluated. These alternatives rely on institutional controls and monitoring to prevent exposure to contaminated ground water until cleanup targets are achieved. Because the contaminant plume is currently discharging to the river, a natural attenuation alternative will not result in additional spreading of the plume. It is estimated that 30 years are required for natural attenuation to reduce contaminant concentrations in ground water to the 10^{-4} level, and 60 years to reach the 10^{-6} risk level. The present worth costs for these alternatives are \$400,000 (10^{-4} target) and \$600,000 (10^{-6} target).

A summary of site conditions and alternative evaluation factors is presented in Table A-8. Table A-9 is a summary of the proposed ground water remedial alternatives. Figure A-6 shows each of the alternatives in the context of the ground water remedial action performance range.

Table A-8
SITE CONDITIONS AND EVALUATION FACTORS
SITE 3

SITE DESCRIPTION:

- Abandoned lagoon; 5 acres

- Source Control: Removal of contaminated materials (sludge, soil, solids, liquids) to residual levels safe for direct contact and ground water

- Hydrogeology: Upper aquifer sands and silty sands. Underlying clay aquiclude.

- Primary Contaminants: Chloroform, ethylbenzene, methyl ethyl ketone

- Plume Characteristics: 60 acres, migrated 1/2 mile to river, migration rate about 25 feet per year.

- Risks: 4×10^{-2} excess lifetime cancer risk, based on maximum contaminant levels in ground water.

- Other Exposure Pathways: Risk from consumption of fish from the river estimated at 1×10^{-8}. Increase in risk in downstream water supply.

GROUND WATER USE AND AVAILABILITY:

- Current Use: No current use because of contamination. Existing wells recently abandoned.

- Projected Use: Limited due to presence of alternate water supply.

- Other Sources: Deeper aquifer. Surface water sources also potentially available, but long-term quality of surface water is uncertain.

- Classification of Contaminated Aquifer: Class IIA characteristics until several residential wells were recently abandoned. It has not been resolved if the ground water classification should be considered to be more like IIB following the abandonment of these wells.

ALTERNATE WATER SUPPLY:

Provided, considered to be of adequate quality and quantity for future needs.

ENVIRONMENTAL PROTECTION:

- No adverse impacts on aquatic life.
- No other environmental receptors.

INSTITUTIONAL CONTROLS:

Expected to be effective and reliable in short term. Long term effectiveness uncertain.

REMEDIAL ALTERNATIVES:

- Technical Feasibility: All alternatives feasible.
- Remediation Levels/Costs/Rate of Restoration: See Table A-9.

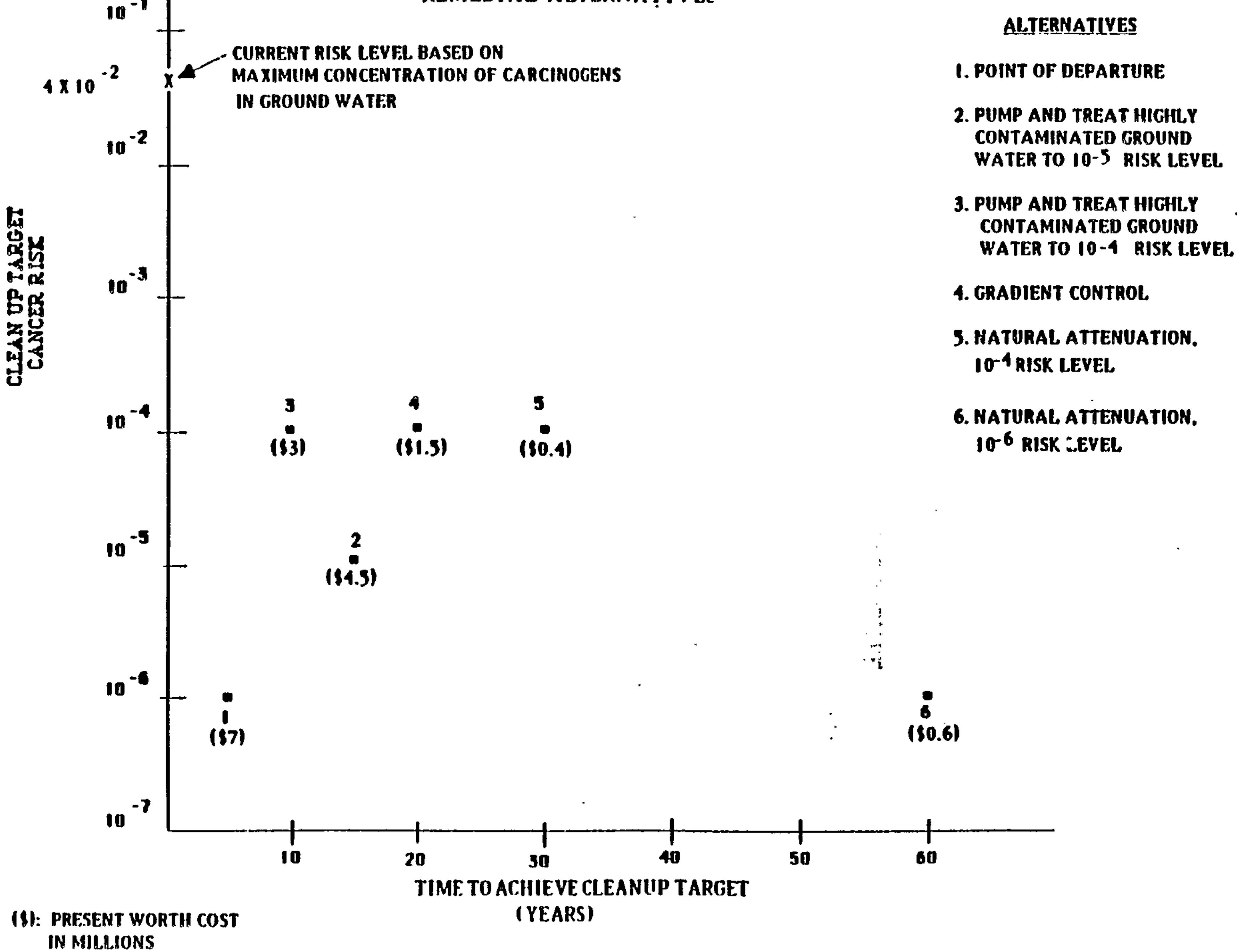
WDR177/025

Table A-9

SITE 3 SUMMARY OF GROUND WATER REMEDIAL ACTION ALTERNATIVES

Alternative	Remediation Target	Duration of Remedial Action	Present Worth Cost	Comments
1. Three extraction wells, carbon adsorption; discharge to river	10^{-6}	5 years	$7 million	Point of departure
2. One extraction well in most contaminated part of the plume; carbon adsorption; discharge to river	10^{-5}	15 years	$4.5 million	
3. One extraction well in most contaminated part of the plume; carbon adsorption; discharge to river	10^{-4}	10 years	$3 million	Recommended alternative
4. Gradient control wells	10^{-4}	20 years	$1.5 million	Long-term institutional controls
5. Natural attenuation	10^{-4}	30 years	$400,000	Long-term institutional controls, potential impacts on surface water supplies
6. Natural attenuation	10^{-6}	60 years	$600,000	As above; longer remedial action but reduces potential for future exposure

SITE 3 - EXPECTED PERFORMANCE OF GROUND WATER REMEDIAL ALTERNATIVES



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DECISION SUMMARY

Because an alternate water supply is available and in use, the emphasis on rapid restoration of the aquifer is diminished. The result is that the advantages of rapid restoration provided by Alternative 1 (point of departure alternative) are not considered to warrant such high costs.

The natural attenuation alternatives depend on the long-term effectiveness of institutional controls to protect public health, and may not provide protection of the river and downstream drinking water supply. There are no current users of ground water, and institutional restrictions are predicted to be quite effective. However, because of the high risk associated with exposures to the most contaminated part of the plume, and the length of time required for contaminant concentration to reach safe levels through natural attenuation, these alternatives are not considered to be adequately protective.

The choice between Alternative 2 (pump and treat the highly contaminated portion of the plume to a 10^{-5} risk level), Alternative 3 (pump and treat to a 10^{-4} risk level), and Alternative 4 (gradient control alternative) involves a risk management decision, balancing the differences in costs among Alternatives 2, 3, and 4 ($4.5 million, $3 million, and $1.5 million, respectively) and the advantages of more rapid restoration (10 years to reach the 10^{-4} risk level for Alternative 3, 15 years to reach the 10^{-5} risk level for Alternative 2, and 20 years to reach the 10^{-4} risk level for Alternative 3). An additional consideration, more difficult to quantify, is the long-term effectiveness of institutional controls. Although the alternate water supply increases the expected effectiveness of institutional controls, the certainty of these controls is expected to decline over an extended period of time. Because of the high risk associated with the most contaminated part of the plume (4×10^{-2}), advantages of more rapid restoration override the additional costs and Alternative 4 is rejected. However, the presence of an alternate water supply reduces the potential for exposure to contaminated ground water, and a 10^{-4} remediation level (Alternative 3) is considered adequately protective.

WDR177/020

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SITE 4--FORMER WOOD TREATING FACILITY--CLASS IIB

GROUND WATER

BACKGROUND

Site 4 is a former wood treating facility where infiltration from an unlined lagoon, leaking drums, and leaking dip tanks have caused soil and ground water contamination. The facility occupies about 15 acres. About 3 acres of the facility are considered to be contaminant source areas. Primary contaminants include pentachlorophenol and PAH compounds. The surface geology consists of sand and silt layers overlying a limestone formation. Solution holes and fractures are common in the upper 20 feet of the limestone. The contaminant plume covers about 10 acres in the unconsolidated deposits. The plume covers less area but has migrated further in the limestone formation, spreading in a complex pattern controlled by the distribution of solution cavities and fractures. The contaminant plume is migrating about 2 feet per year in the unconsolidated deposits. The maximum migration rate in the limestone is estimated at 5-feet per year. However, future migration rates are difficult to predict.

Pentachlorophenol levels in sludge and soils are in the 1,000 to 10,000 mg/kg range, and PAH compounds are in the

500 to 1,000 mg/kg range. Ground water contaminant concentrations are highest in the unconsolidated deposits, with PAH concentrations as high as 200 μg. The maximum PAH concentrations measured in the limestone formation was 15 μg/l. Cancer risks for drinking water associated with the maximum contaminant levels measured in the ground water are 6×10^{-2} in the unconsolidated deposits, and 5×10^{-3} in the limestone formation. Pentachlorophenol concentrations were measured as high as 15 mg/l in the unconsolidated deposits and 2 mg/l in the limestone formation, above the EPA Adjusted Ambient Water Quality Criteria for pentachlorophenol of 1.01 mg/l. Table A-10 summarizes concentrations, health-based levels, and mobility characteristics of contaminants in ground water. Figure A-7 shows a conceptual diagram of site conditions.

Land uses around the site include commercial warehousing and industrial facilities. Future land uses are assumed to remain primarily industrial and commercial. The area is served by a municipal water system. A survey conducted during the RI showed that there are no drinking water wells within two miles of the site, and the ground water has the characteristics of a Class IIB aquifer. Published information indicates that a deeper water-bearing unit may be present below the fractured limestone, but the water supply potential of that unit has not been determined for the area around the site.

Table A-10
PRIMARY CONTAMINANTS AT SITE 4

Contaminant	Maximum Concentration Detected (ug/l)	AWQC (ug/l)	Drinking Water Health Advisory (ug/l)	Excess Lifetime Cancer Risk	Koc
PAHs	200	(0.003)	--	$6x10^{-2}$	1000 to >1,000,000
Pentachlorophenol	15,000	1010	1050	N/A	53,000

AWQC: EPA Ambient Water Quality Criteria for drinking water only.

--: No criteria or advisory given.

N/A: Compound is not currently listed as a carcinogen.

Values in parentheses associated with the 10^{-6} excess lifetime cancer risk.

Carcinogenic risk calculated based lowest value associated with 10^{-6}.

K_{oc}: Organic carbon partition coefficient.

Reference: Superfund Public Health Evaluation Manual.

WDR177/030

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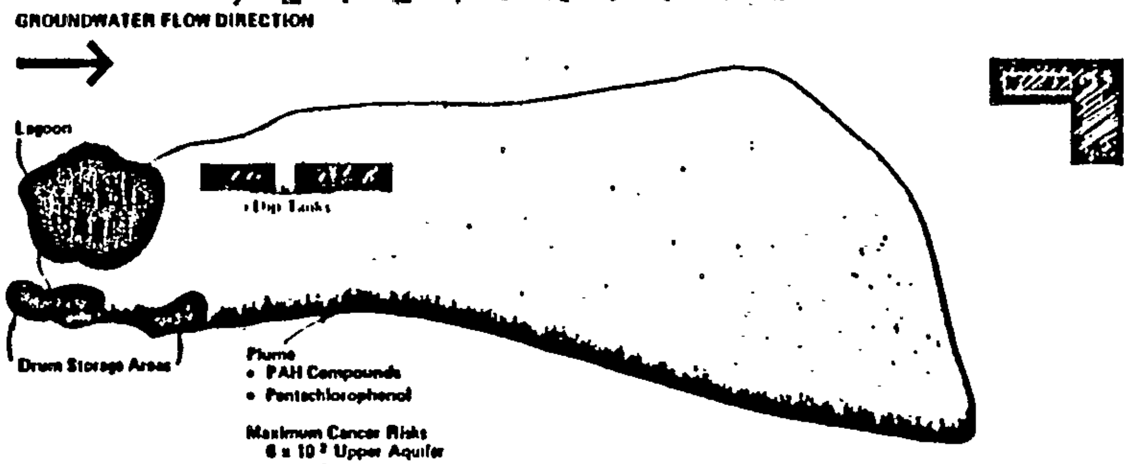
Plan View



Section View

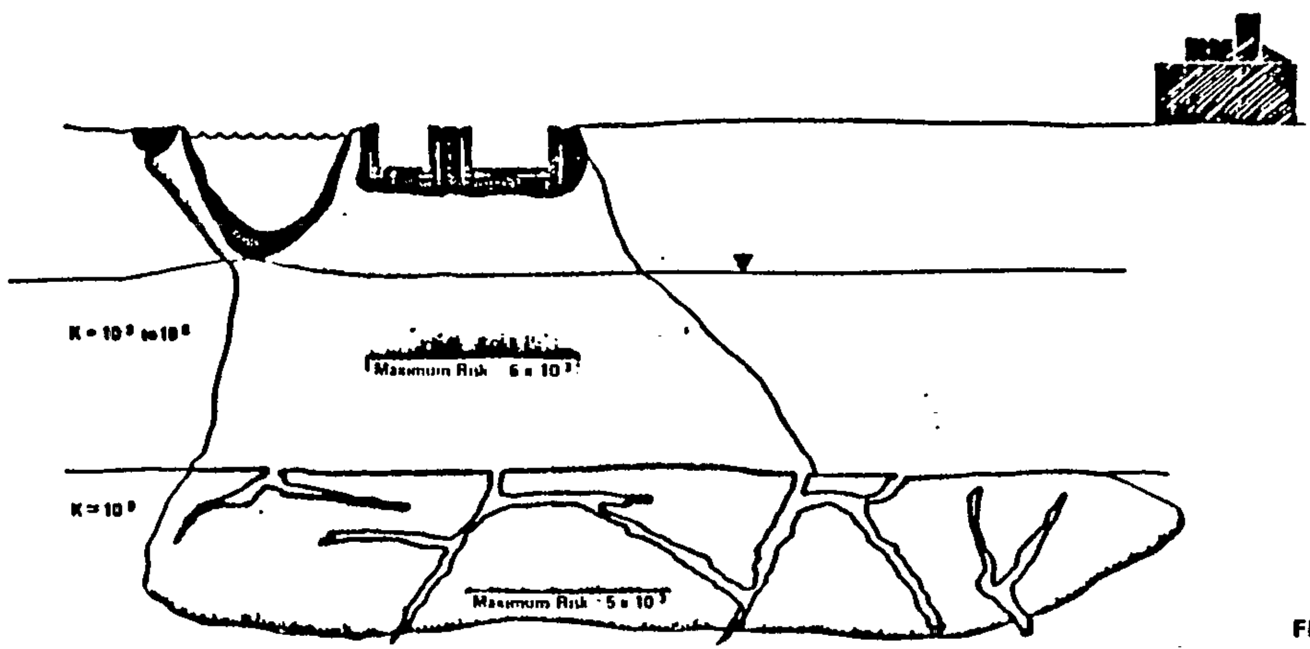


Figure A-7
CASE STUDY 4
SITE LAYOUT

RESPONSE OBJECTIVES

Response objectives for the site include:

- o Preventing direct contact with contaminated soils and sludges at the site;
- o Minimizing continued migration of contaminants in the aquifer;
- o Preventing exposure to currently contaminated ground water;
- o Protecting uncontaminated ground water for current and future use; and
- o Restoring contaminated ground water for future use.

DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES

The source control remedial action will consist of the following:

- o Pumping lagoon liquids, pretreating onsite, and discharging to the local publicly-owned treatment works (POTW);

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- o Excavating contaminated sludge and soils, incinerating onsite, and backfilling the lagoon with residuals;

- o Constructing a clay cap over the site; and

- o Subsurface drains to collect leachate.

The source control remedial action is expected to reduce contaminant concentrations in leachate migrating to the ground water to a 10^{-4} cancer risk level.

Six ground water remedial alternatives have been evaluated in detail for the site. These alternatives include:

1. Pump and treat to the 10^{-6} cancer risk level in 5 years (point of departure alternative)

2. Pump and treat to the 10^{-4} cancer risk level in 40 years

3. Gradient control wells with low permeability cap to prevent continued migration of the contaminants. Contaminant levels are expected to reach the 10^{-4} cancer risk level in 50 to 60 years

4. In-situ biodegradation to the 10^{-4} level in 20 to 50 years

5. Natural attenuation to the 10^{-4} cancer risk level in 100 to 200 years

6. Natural attenuation to the 10^{-6} level in more than 250 years

<u>Point of Departure Alternative</u>

Because of the extremely low mobilities of PAH compounds (K_{oc} values estimated to range from the 1,000's to more than one million), an aggressive flushing system will be necessary if contaminants are to be mobilized and rapidly removed from the subsurface. To meet the performance criteria for the point of departure alternative, this alternative combines solvent and detergent flushing system to facilitate transport of pentachlorophenol and PAH compounds, a slurry wall and extraction well network to recover contaminants and flushing solutions, treatment by air stripping and carbon adsorption, and discharge to the local POTW. Flushing solutions would be applied through a network of 20 shallow injection wells.

Increasing the mobility of these highly toxic compounds also increases the potential for more widespread contamination and an extensive ground water recovery system is included in the conceptual design. Ten recovery wells would be completed in both the unconsolidated and limestone formations. A slurry wall would be constructed downgradient of the recovery wells to increase contaminant removal efficiencies and to retard contaminant migration if the recovery wells fail. The slurry wall would be constructed to a depth of about 90 feet in order to ensure the wall is keyed to the limestone formation below the zone of fractures and extensive solution hole formation. The technical feasibility of constructing a slurry wall to this depth remains uncertain. A series of treatment steps, including stripping of volatiles followed by carbon adsorption, will be required prior to discharge to the POTW.

This alternative involves a complex combination of innovative technologies. The present worth costs are expected to range between $50 million and $125 million. These costs are difficult to predict because of the high level of uncertainty concerning the feasibility of construction and long-term effectiveness of the remedial action.

Other Alternatives in the Performance Range

Based on the evaluation of the point of departure alternative, the EPA Regional Project Manager determined that it was not technically feasible to construct and operate a ground water remedial alternative that achieved the performance range goals of reducing carcinogen levels to the 10^{-4} to 10^{-7} range in no longer than several decades. Other active restoration alternatives were developed that approach the level of protection and rate of restoration in the performance range to the maximum extent that is feasible.

<u>Other Active Restoration Alternatives</u>

A conventional pump and treat system without soil flushing or slurry wall construction is expected to achieve a 10^{-4} cleanup level in 40 years. Because no flushing solutions will be added to the aquifer, the mobility of the PAH compounds will not be altered. The effectiveness of the recovery wells in removing PAH compounds from the subsurface soils is uncertain. The present worth cost for this alternative is estimated at $25 million.

The third alternative includes placement of a low-permeability cover along with gradient control wells to minimize further migration of the contaminant plume. The wells will be designed to contain the plume with or without the slurry wall, with the wall improving recovery efficiency and providing additional protection against migration if the recovery wells are shut down. This alternative is expected to reduce contaminant concentrations to the 10^{-4} level in 50 to 60 years. The present worth cost of this alternative is estimated at $15 million.

An in-situ biodegradation alternative includes several steps: development of a bacteria capable of degrading PAH compounds as well as toxic intermediate breakdown products; introduction of these bacteria into the subsurface; dispersing these bacteria through the contamination zone; and maintaining proper nutrient, oxygen, and pH levels to promote microbial activity. All of the technologies involved are either innovative or experimental, and a one- to three-year pilot study is recommended to determine the feasibility and potential effectiveness of this alternative. Assuming that the technical obstacles are resolved, accelerated degradation rates are expected to reduce carcinogen concentrations to the 10^{-4} level within a time period ranging from 20 to 50 years. The present worth cost of this alternative is estimated at $10 million. The cost of the pilot study alone is estimated at $2 million.

Natural Attenuation Alternatives

The time required for natural attenuation processes to reduce PAH compounds to the 10^{-4} level is estimated to range from 100 to 200 years. The time required for natural

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attenuation to the 10^{-6} level is estimated at more than 250 years. The present worth costs for monitoring are estimated at \$2 million to \$3 million for the 10^{-4} risk level, and \$ 3.5 million for the 10^{-6} risk level. These natural attenuation alternatives would not prevent significant spreading of the contaminant plume over time.

DECISION SUMMARY

The low mobility of the principal contaminants along with the complex and poorly understood flow patterns in the aquifer greatly increase the technical complexity and the uncertainty over the effectiveness of any of the active restoration alternatives. The point of departure alternative is rejected because it is not considered technically feasible. A significant disadvantage to this alternative is that the increase in contaminant mobility resulting from the injection of solvent and detergent flushing solutions may result in more widespread contamination.

The second pump and treat alternative eliminates the most technically complex elements of the point of departure alternative. However, the present worth cost of the alternative is very high, and the effectiveness of the alternative is uncertain.

The natural attenuation alternatives are rejected because of the high degree of risk if institutional controls are deliberately or unknowingly violated, the extended period (over 100 years) required until contaminant levels are expected to reach safe levels, and the significant expansion of the contaminant plume which would occur before these levels are reached. The effectiveness and reliability of institutional controls are highly uncertain over such time periods.

The in-situ biodegradation alternative is an innovative approach that is potentially cost-effective. However, the technologies required at this site have not been demonstrated under similar conditions, and the degree of uncertainty is considered very high.

The gradient control alternative is recommended for this site. This alternative is expected to eliminate the continued migration of contaminants, and will reduce contaminant concentrations to performance range levels in significantly less time than the natural attenuation alternatives. However, institutional controls restricting ground water use will be required for 50 to 60 years over an area of about 40 acres.

A summary of site conditions and alternative evaluation factors is presented in Table A-11. Table A-12 is a summary of the ground water remedial alternatives. Figure A-8 shows each of the alternatives in the context of the ground water remedial action performance range.

WDR177/021

Table A-11
SITE CONDITIONS AND EVALUATION FACTORS
SITE 4

SITE DESCRIPTION:

- Abandoned Wood Treating facility, 15 acres

- Source Control: Pumping and treating liquids, incinerating sludges and contaminated soils, clay cap, leachate collection.

- Hydrogeology: Sands and silts overlying karst limestone formation.

- Primary Contaminants: PAH compounds, pentachlorophenol

- Plume Characteristics: 10 acres, in overlying unconsolidated deposits, further migration in limestone. Plume migration rate estimated at 2 feet per year in upper zone, 5-feet per year in limestone.

- Risks: 6×10^{-2} excess lifetime cancer risk, based on maximum contaminant levels in ground water.

- Other Exposure Pathways: Direct contact, until source control actions implemented.

GROUND WATER USE AND AVAILABILITY:

- Current Use: No drinking water wells within 2 miles of the site. Commercial and industrial facilities in th area are served by a municipal water system.

- Projected Use: None expected

- Other Sources: Deeper geologic unit has aquifer potential; but no actual well data available.

ALTERNATE WATER SUPPLY:

Municipal water system in use. No known alternative to the existing system.

ENVIRONMENTAL PROTECTION:

No environmental receptors identified.

INSTITUTIONAL CONTROLS:

Expected to be effective in the near term. Long term effectiveness uncertain.

REMEDIAL ALTERNATIVES:

- Technical Feasibility: Alternative 1 (point of departure) judged infeasible. Feasibility of in-situ treatment uncertain.

- Remediation Levels/Costs/Rate of Restoration: See Table A-12.

WDR177/026

Ta. A-12

SITE 4 SUMMARY OF GROUND WATER REMEDIAL ACTION ALTERNATIVES

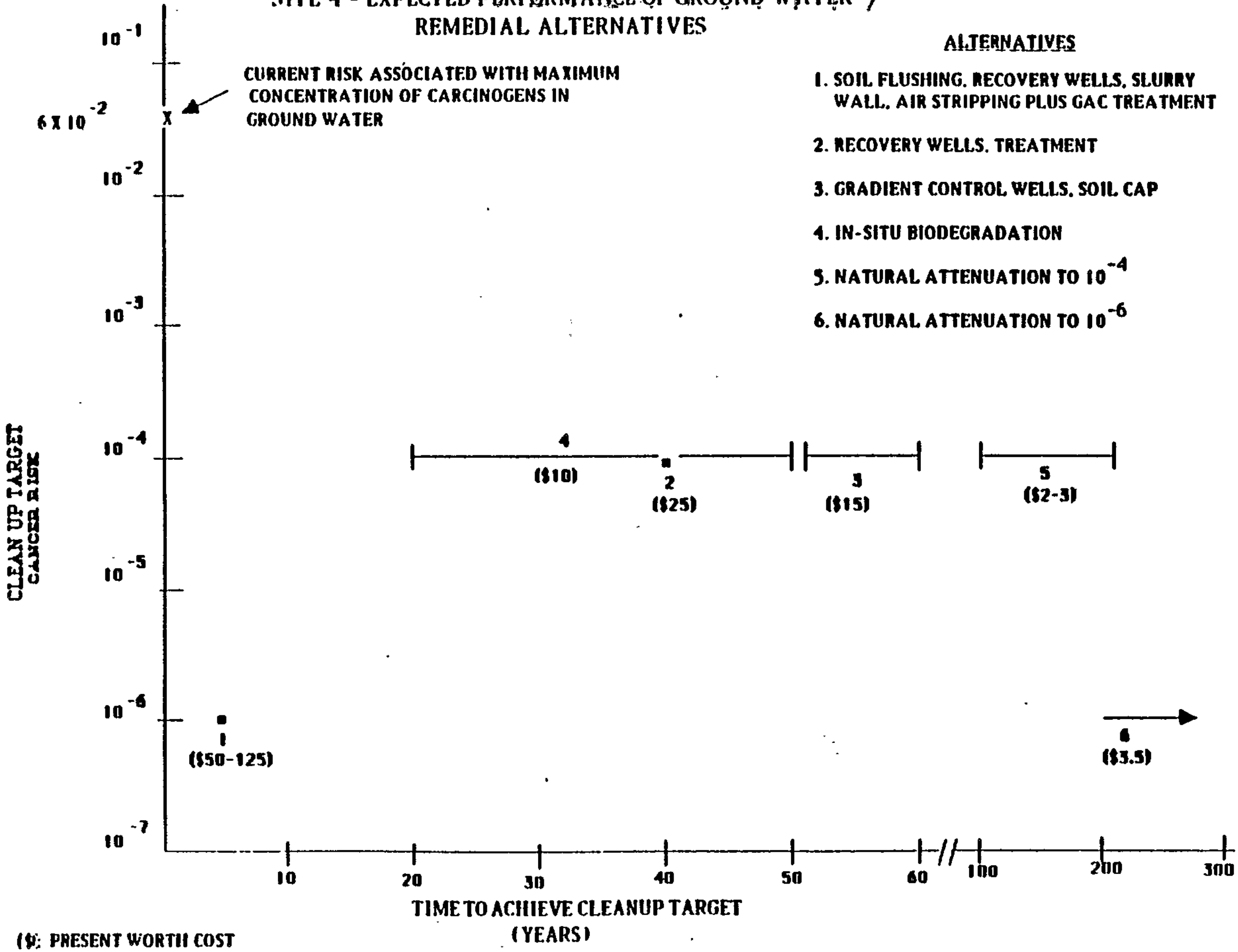
Alternative	Remediation Level	Duration of Remedial Action	Present Worth Cost	Comments
1. Soil washing with recovery wells, slurry wall, volatile stripping plus carbon adsorption, discharge to POTW	10^{-6}	5 years	\$50 million to \$125 million	Point of departure; rejected based on Fund balancing, technical feasibility, consequences of recovery system failure
2. Recovery wells, treatment, discharge to POTW	10^{-4}	40 years	\$25 million	High cost and uncertain effectiveness
3. Gradient control wells, soil cap	10^{-4}	50-60 years	\$15 million	Recommended alternative; contains plume, gradually reducing contaminant levels
4. In-situ biodegradation	10^{-4}	20-50 years	\$10 million	Unproven technologies, highly uncertain effectiveness
In-situ pilot study		1-3 years	\$2 million	
5. Natural attenuation to 10^{-4} cancer risk	10^{-4}	100-200 years	\$2 to 3 million	Contaminants continue to migrate, institutional controls unreliable over extended period, high risks if exposure occurs
6. Natural attenuation to 10^{-6} cancer risk	10^{-6}	>250 years	\$3.5 million	As above.

WDR163/044

FIGURE A-8

SITE 4 - EXPECTED PERFORMANCE OF GROUND WATER 7

REMEDIAL ALTERNATIVES



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SITE 5--TEXTILE DYEING PLANT--CLASS IIA GROUND WATER

BACKGROUND

Site 5 is an abandoned textile dyeing plant, located in the piedmont in the southeast. Dye carriers and spent solvents had been disposed in open vats that would overflow when it rained. The solvent disposal area covers about 0.5 acres of the 3-acre plant. Nearby residents complained of solvent vapors from the property. The solutions emptied into the vats contained toluene, phenol, naphthalene, and trichloroethane. Toluene levels were measured as high as 2,000 mg/kg in soils and 200 mg/l in ground water. Maximum concentrations in ground water for other primary contaminants were 55 mg/l phenol, 5 mg/l naphthalene, and 2 μg/l of 1,1,1-trichloroethane.

The upper aquifer consists of fine to medium sands with thin layers of silt, ranging from 50 to 60 feet in total thickness, with the water table about 7 feet below the surface. The upper aquifer is underlain by dense and low-permeability sediments. This lower formation yields low to very low quantities of water, except at widely scattered contact zones between the fine grained sediments and igneous intrusions. Ground water at the site flows to a creek which borders the plant property, about 300 feet downgradient of

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the solvent spill area. Ground water velocity at the site is estimated at 35 feet per year. The plume is estimated to be migrating at 10 feet per year, although individual contaminants are migrating at different rates depending on soil adsorption properties.

Toluene and phenol concentrations in creek sediments were measured as high as 150 mg/kg and 100 mg/kg, respectively. Maximum toluene concentrations in water samples taken from the creek were 20 mg/l and 5 mg/l, respectively. Table A-13 summarizes data on environmental concentrations, human health, aquatic toxicity, and mobility data for the primary contaminants.

The nearest private wells are on the opposite side of the creek, about 500 feet downgradient of the site. Local residents use the stream for swimming and fishing. The creek is apparently an effective ground water flow barrier, as ground water contaminant levels are much lower on the opposite side. The highest toluene and phenol levels measured in drinking water wells were 30 μg/l and 5 μg/l, respectively. Figure A-9 shows the conceptual layout for the site. Land use around the site consists of low density residential areas, widely scattered industries, and small farms. The site is 60 miles from a major city, and only limited growth is anticipated. Institutional controls

Table A-13
PRIMARY CONTAMINANTS AT SITE 5

Contaminant	Ground Water Maximum Concentration Detected (ug/l)	Surace Water Maximum Concentration Detected (ug/l)	AWQC (ug/l)	Drinking Water Health Advisory (ug/l)	Toxicity, Freshwater Aquatic Life (ug/l)	Excess Lifetime Cancer Risk	Koc
Toluene	200,000	20,000	15,000	10,100	17,500 (acute)	N/A	300
Phenol	55,000	5,000	3,500	--	2,560 (chronic)	N/A	14.2
Naphthalene	1000	10	--	--	620	N/A	1300
1,1,1-Trichloroethane	2.0	<1.0	--	(22)	--	$1x10^{-7}$	152

AWQC: EPA Ambient Water Quality Criteria for drinking water only.

--: No criteria or advisory given.

N/A: Compound is not currently listed as a carcinogen.

Values in parentheses associated with the 10^{-6} excess lifetime cancer risk.

Carcinogenic risk calculated based lowest value associated with 10^{-6}.

K_{oc}: Organic carbon partition coefficient.

Reference: Superfund Public Health Evaluation Manual and Federal Register, Vol. 45, No. 231, 11/28/80.

WDR177/031

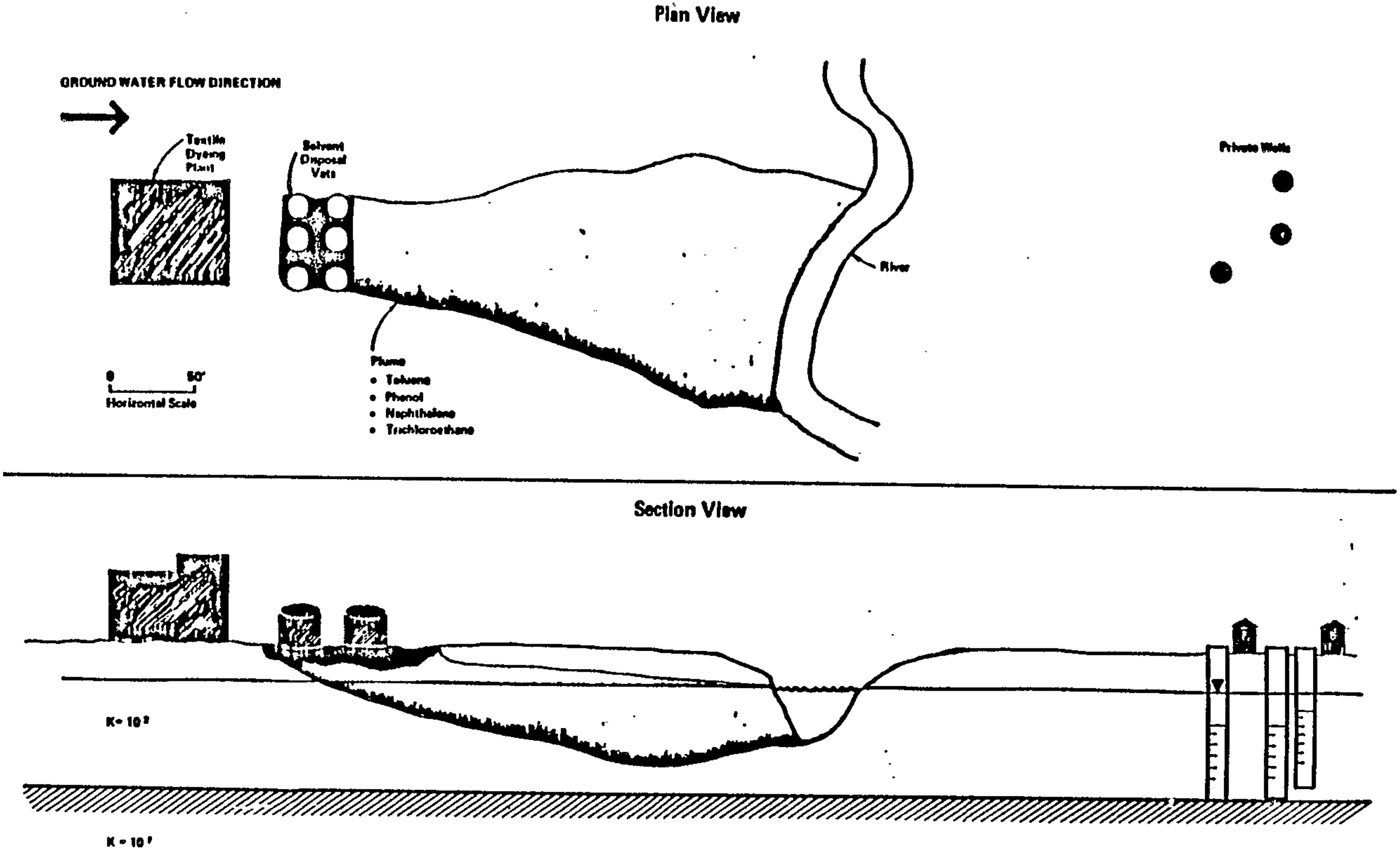

Figure A-9
CASE STUDY 5
SITE LAYOUT

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restricting ground water use are not expected to be effective in this geographically isolated setting.

Removal actions taken at the site included emptying the solvent vats and removing the upper foot of soil around the vat storage area. This action substantially reduced the loss of volatiles to the air.

RESPONSE OBJECTIVES

Response objectives for this site include:

- o Preventing exposure to contaminated ground water;
- o Protecting uncontaminated ground water for current and future use;
- o Restoring contaminated ground water for future use;
- o Preventing exposure through direct contact with contaminated soils;
- o Preventing exposure through inhalation and food chain pathways; and
- o Protecting surface water quality.

As shown in Table A-13, only one of the primary contaminants, 1,1,1-trichloroethane, is a carcinogen. The excess cancer risk from trichloroethane in ground water is below the 10^{-6} level at all locations in the aquifer. The toxicities to human health of the noncarcinogenic contaminants are moderately low compared to carcinogenic contaminants (no human health levels were reported for naphthalene). The adjusted ambient water quality criteria (for consumption of drinking water only) is 15 mg/l for toluene and 3.5 mg/l for phenol. Toluene and phenol concentrations beyond the property boundary are a maximum of 30 ug/l and 5 ug/l, respectively, and do not pose a threat to human health. The Risk Assessment reports that no action is necessary to protect human health from ground water contamination.

Although solvents continue to volatilize from the site, the removal action reduced contaminant concentrations in the air to safe levels. In addition, the removal of highly contaminated soils has reduced the potential hazards for direct contact. The total risks to human health based on all potential exposure pathways (ground water, dermal contact, inhalation, ingestion of contaminated soil, and fish consumption) indicated that the site does not pose a threat to human health.

The discharge of contaminated ground water to the creek has had an impact on surface water quality. Toluene levels in the creek have been measured at 20 mg/l, above the ambient water quality acute toxicity level for freshwater aquatic life of 17.5 mg/l (no data is available on chronic toxicity levels). Maximum phenol concentrations in the creeks are 5 mg/l, above the chronic toxicity level for freshwater aquatic life of 2.6 mg/l. These surface water concentrations are expected to rise when more highly contaminated ground water reaches the creek.

DEVELOPMENT OF REMEDIAL ACTIONS

Because there is no remaining threat from direct contact at the site, the effectiveness of source control alternatives was evaluated strictly on the basis of impacts on ground water contamination, and subsequent effects on water quality in the creek. Source control remedial alternatives evaluated included:

1. Removal of contaminated soils and placement in an onsite landfill

2. Enhanced volatilization with vapor recovery

3. Enhanced volatilization without vapor recovery

4. Placement of a RCRA cap

5. No action

These source control alternatives were evaluated in combinations with the ground water alternatives described below.

Proposed ground water remedial actions include:

1. Pumping and treating to reduce contaminant levels in ground water below adjusted ambient water quality criteria within five years

2. Gradient control wells

3. Natural attenuation

The pump and treat alternative consists of two extraction wells; one below the solvent vat storage area and the other closer to the creek, followed by air stripping and discharge to the creek. The alternative is designed to reduce toluene and phenol concentrations to adjusted ambient water quality criteria levels directly below the waste management area within 5 years. Contaminant levels in the creek are expected to reach levels that are safe for aquatic life within 6 months. The present worth cost of the alternative is $2.5 million.

The gradient control alternative consists of a low-discharge recovery well that prevents the contaminant plume from flowing into the creek. Contaminant concentrations in surface waters would be expected to reach safe levels within one year. The gradient control wells would be operated for 5 years, at which time natural discharge of ground water to the creek would not be harmful to aquatic life. The present worth cost of this alternative is $200,000. In order to reduce contaminant levels to water quality criteria in the ground water below the site, the gradient control wells would have to be operated for 20 years, at a present worth cost of $2 million.

The natural attenuation alternative relies on dilution and degradation to reduce contaminant concentrations to safe levels. Contaminant concentrations in surface waters would be expected to reach safe levels within 10 years. No media outside of the site property boundary poses a threat to human health, so no institutional control restricting ground water use would be required. The present worth cost of this alternative is estimated at $40,000. It is estimated that 50 years would be required to achieve safe drinking water levels directly below the site through natural attenuation.

The present worth cost of monitoring is estimated to be $400,000.

A summary of site conditions and alternative evaluation factors is presented in Table A-14. Table A-15 is a summary of proposed ground water remedial alternatives.

DECISION SUMMARY

Performance goals for ground water cleanup targets are generally established within a particular attainment zone that extends from the boundary of the plume back to the contaminant source. At Site 5, the source is about 300 feet inside of the property boundary. Beyond the property boundary ground water contaminant concentrations are below levels that are fully protective of human health. Institutional controls restricting ground water use are expected to be highly effective within the property boundary, and no additional ground water remedial actions are required to protect human health. However, the goals of Superfund include protection of both human health and the environment, and environmental concerns justify a remedial action at this site.

The recommended alternative combines enhanced volatilization with vapor recovery as the source control operable unit, along with a gradient control well to minimize the discharge of contaminants to the creek. Enhanced volatilization will

Table A-14
SITE CONDITIONS AND EVALUATION FACTORS
SITE 5

SITE DESCRIPTION:

- Abandoned Textile Dyeing Plant, 3 acres

- Source Control: Emptying solvent vats, removal of upper foot of soil. Further source control alternatives under consideration.

- Hydrogeology: Contaminated aquifer consists of fine to medium sands. Ground water velocity estimated at 35 feet per year.

- Primary Contaminants: Toluene, phenol, nephthalene, 1,1,1-trichloroethane

- Plume Characteristics: Plume extends 300 feet from vat storage area to creek. Water quality data indicates that most of the plume discharges to the creek. Plume migration rate estimated at 10 feet per year.

- Risks: No risks to human health beyond site boundary.

- Other Exposure Pathways: Food chain, dermal contact in surface water, and inhalation pathways do not pose a threat to human health.

GROUND WATER USE AND AVAILABILITY:

- Current Use: About 20 drinking water wells within a quarter mile of the site, all located on the opposite side of the river.

- Projected Use: No change in current use expected.

- Other Sources: Other ground water sources uncertain in terms of sufficient quantity and quality. Surface water unreliable in terms of seasonal variations in flow and susceptibility to contamination.

ALTERNATE WATER SUPPLY:

No existing alternative supply. Some potential for developing lower geologic formation if wells are located along high-yield igneous contact zones.

ENVIRONMENTAL PROTECTION:

Contamination from the site is a current hazard to aquatic life in the creek.

INSTITUTIONAL CONTROLS:

Effectiveness and reliability expected to be high within the site boundary. Effectiveness outside of the property boundary uncertain in this geographically isolated setting.

REMEDIAL ALTERNATIVES:

- Technical Feasibility: All alternatives technically feasible.
- Remediation Levels/Costs/Rate of Restoration: See Table A-15.

WDR177/027

SITE 5 SUMMARY OF GROUND ...TER REMEDIAL ACTION ALTERNATIVES

Alternative	Remediation Level	Duration of Remedial Action	Present Worth Cost	Comments
1. Pump and treat	Ambient Water Quality Criteria for toluene and phenol in ground water below the site (within the site boundary)	5 years	$2.5 million	Based on achieving safe drinking water levels directly below the waste management area
	Water Quality Criteria for aquatic life in the creek	6 months	$1.5 million	Based on protection of aquatic life
2. Gradient control	Ambient Water Criteria for for toluene and phenol in ground water below the site (within the site boundary)	20 years	$2 million	Based on achieving safe drinking water levels directly below the waste management area
	Water Quality Criteria for aquatic life in the creek	1 year	$200,000	Recommended alternative; based on protection of aquatic life
3. Natural attenuation	Ambient Water Quality Criteria for toluene and phenol in ground water below the site (within the site boundary)	50 years	$400,000	Based on achieving safe drinking water levels directly below the waste management area
	Water Quality Criteria for aquatic life in the creek	10 years	$40,000	Based on protection of aquatic life

involve periodic tilling of the soil, mixing the soil surface over a depth of 30 inches. Soil leachate contaminant concentrations are expected to be reduced five times more quickly through enhanced volatilization as compared to the no action alternative for source control.

The gradient control alternative is selected because it will provide substantial environmental protection benefits over the no action alternative for ground water. The more aggressive pump and treat alternatives is not considered cost-effective.

WDR177/022

SITE 6--ABANDONED DUMP--CLASS III GROUND WATER

BACKGROUND

Site 6 is an abandoned hazardous waste dump which occupies 2 acres of a former gravel pit. For many years area residents have hunted on the site, and continue to do so in the vicinity of the pit. An estimated 1,000 buried drums containing liquids and solids were disposed of at the site. Soils below the drums are contaminated to a depth of about 3 feet.

The upper aquifer consists of coarse sand and gravel and has characteristics of Class III ground water. The ground water is unsuitable for consumptive use because of high levels of dissolved solids (TDS ¶10,000 mg/l). The lower sandstone aquifer is less saline (TDS about 1,000 mg/l), and has the characteristics of Class IIA (current use) aquifer. The RI investigation confirmed that the confining bed prevents the migration of wastes from the shallow to the deeper aquifer. The closest downgradient well (in the lower aquifer) is 1,000 feet downgradient of the plume.

A plume of trichloroethylene (TCE) is migrating through the upper aquifer. The maximum concentration of TCE in ground water was measured at 200 µg/l. The AWQC for TCE based on a carcinogenic risk of 10^{-6} is 2.8 µg/l, and the risk associated with maximum TCE levels is 7 x 10^{-5} (Table A-16). There is concern that TCE will degrade to vinyl chloride, which is a more potent carcinogen. However, monitoring data do not show vinyl chloride in the plume, and the concentrations of TCE decrease rapidly with distance away from the site because of rapid natural attenuation of contamination. The plume covers a 10-acre area and is migrating at a rate of about 5-feet per year. The ground water discharges in saline springs and seeps along the banks of a river about one mile downgradient. No TCE is expected to be present at the discharge point. Figure A-10 presents a conceptual view of the site.

Surrounding land use includes recreational and agricultural activities, and some residential use. Residential use is expected to increase in the future. The effectiveness of institutional controls restricting ground water use is uncertain.

RESPONSE OBJECTIVES

Response objectives for the site include:

- o Prevent direct contact with hazardous materials and highly contaminated soils

Table A-16
PRIMARY CONTAMINANTS AT SITE 6

Contaminant	Maximum Concentration Detected (ug/l)	AWQC (ug/l)	Drinking Water Health Advisory (ug/l)	Excess Lifetime Cancer Risk	Koc
TCE	200	2.8	2.8	$7x10^{-5}$	126

AWQC: EPA Ambient Water Quality Criteria for drinking water only.

--: No criteria or advisory given.

NA: Compound is not currently listed as a carcinogen.

Values in parentheses associated with the 10^{-6} excess lifetime cancer risk.

Carcinogenic risk calculated based lowest value associated with 10^{-6}.

K_{oc}: Organic carbon partition coefficient.

Reference: Superfund Public Health Evaluation Manual.

WDR177/045

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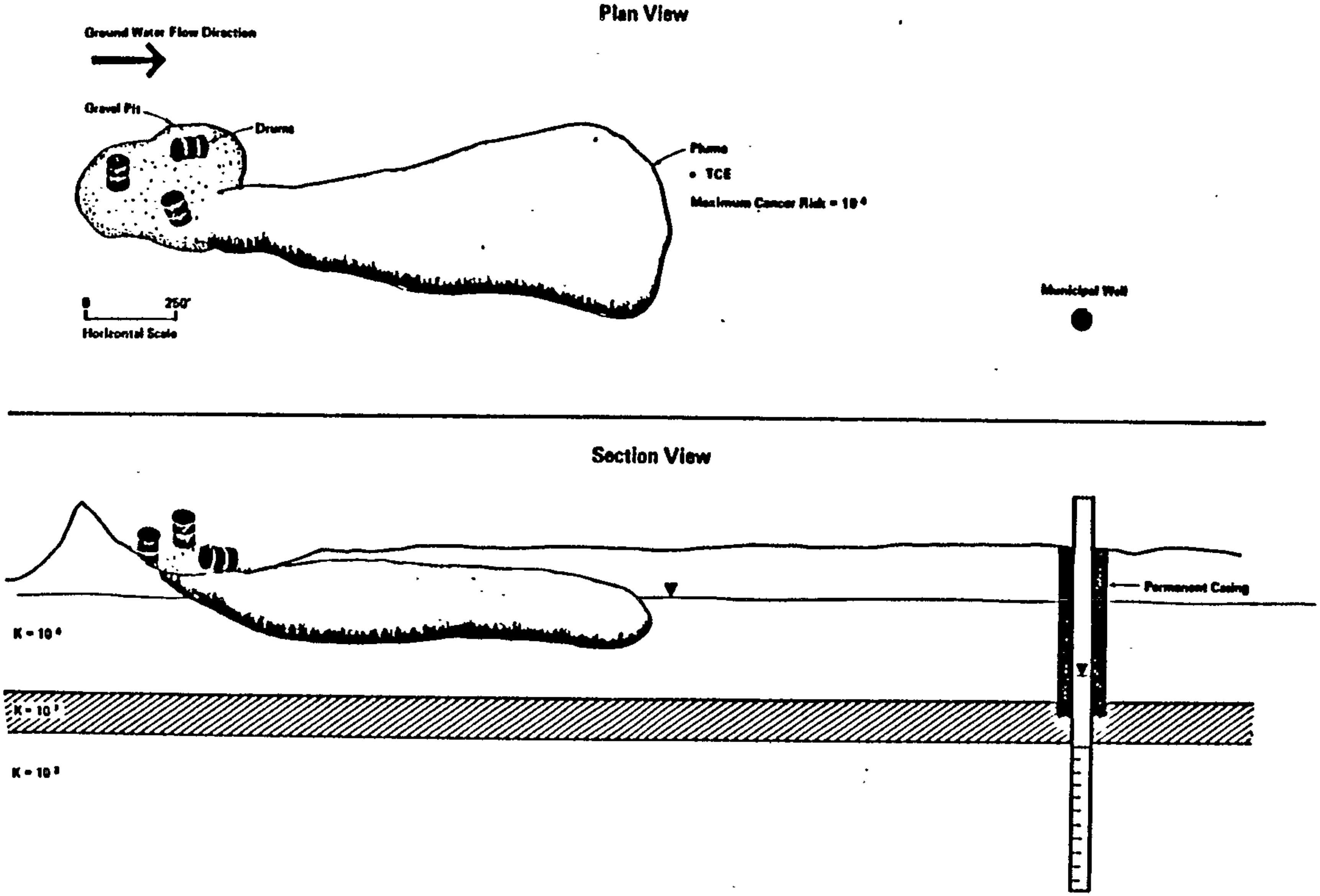

Figure A - 10
CASE STUDY 6
SITE LAYOUT

- Prevent exposure to contaminated aquifer (Class III)

- Protect lower aquifer (Class IIA) from contamination

Direct contact is a major concern because of the presence of high hazard materials in the pit combined with the accessibility of the site. Of the ground water response objectives, protection of the uncontaminated lower aquifer is of primary importance. Exposure to the contaminated shallow aquifer is less of a concern, because the aquifer is not suitable for consumptive use.

DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES

Proposed source control remedial alternatives include:

1. Removal of drums, liquids, and contaminated soils, all to be treated or disposed offsite ($8 million).

2. Removal of drums and liquids for offsite treatment, and excavation of contaminated soils and burial in an onsite landfill ($6 million).

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3. Removal of drums and liquids for offsite treatment, backfilling the pit, and constructing a clay cap over contaminated soils and other residuals ($3 million).

4. Constructing a RCRA-type cap, leaving all wastes in place ($2 million).

5. No action.

The no action alternative is rejected because of the direct contact threat. Alternatives 1 and 2 are rejected because of the marginal benefits to human health or the environment from soil removal where the contaminated aquifer has characteristics of Class III ground waters.

Alternative 3 is expected to be more effective than Alternative 4 at reducing contaminant migration, but is more costly. This tradeoff is considered in light of the classification of the ground waters, the potential for contaminating the lower aquifer, and other ground water remedial action evaluation factors discussed below.

Proposed ground water remedial actions include:

1. Pumping and treating the upper aquifer to achieve a 10^{-6} risk level in 5 years. The present worth cost of this alternative is $1.7 million.

2. Construction of a slurry wall combined with pumping to prevent further migration of the plume. The present work cost of this alternative is $1 million.

3. Natural attenuation plus monitoring and institutional controls. The present worth cost of this alternative is $100,000.

A summary of site conditions and decision evaluation factors is presented in Table A-17. Table A-18 is a summary of ground water remedial alternatives.

DECISION SUMMARY

Alternative 1 is an active restoration alternative that has the characteristics of the point of departure alternative within the ground water remedial action performance range. However, the performance range concept applies primarily to ground waters with Class I and Class II characteristics, and may not be a useful evaluation tool at sites where ground water with Class III characteristics has been contaminated. At this site, the active restoration alternative is not considered cost-effective.

The containment alternative prevents the continued spread of contaminants, therefore reducing the area over which institutional controls are applied. The natural attenuation

Table A-17
SITE CHARACTERISTICS AND EVALUATION FACTORS - SITE 6

SITE DESCRIPTION:

- Abandoned dump, 2 acres

- Source Control: Not implemented. Critical to ground water remedial action.

- Hydrogeology: Upper aquifer coarse sand and gravel, highly saline (TDS ¶10,000 mg/l). Lower aquifer sandstone. Aquifers separated by confining bed.

- Primary Contaminants: TCE

- Plume Characteristics: 10 acres, migrating 5 feet per year. Contaminant levels decrease rapidly via natural attenuation.

- Risks: 7×10^{-5} excess lifetime cancer risk, based on maximum TCE level in ground water.

- Other Exposure Pathways: Direct contact.

GROUND WATER USE AND AVAILABILITY:

- Current Use: No current use of contaminated aquifer because of high salinity.

- Projected Use: None.

- Other Sources: Sandstone aquifer beneath contaminated aquifer.

- Ground Water Classification: Upper aquifer has characteristics of Class III. Lower aquifer has characteristics of Class IIA.

ALTERNATE WATER SUPPLY

Lower aquifer currently supplies drinking water needs. No other alternative supply available.

ENVIRONMENTAL PROTECTION

No environmental receptors/impacts.

INSTITUTIONAL CONTROLS

Potentially effective and reliable in short term. Long term effectiveness uncertain.

REMEDIAL ALTERNATIVES

Technical Feasibility: All alternatives feasible.

Remediation Levels/Costs/Rate of Restoration: See Table A-18.

WDR177/046

Table A-18
SITE 6 - SUMMARY OF GROUND WATER REMEDIAL ALTERNATIVES

Alternative	Cleanup Target	Duration of Remedial Action	Present Worth Cost	Comments
1. Pump ground water; treat with air stripping and GAC, reinject	10^{-6}	5 years	$1.7 million	Rapid restoration of ground water to levels that are safe to drink is generally not cost-effective for Class III aquifers
2. Slurry wall plus gradient control wells	10^{-6}	15 years	$1 million	
3. Natural attenuation	10^{-4}	25 years	$100,000	Recommended alternative - combined with effective source control action

WDR163/047

alternative, on the other hand, requires institutional controls over the current extent of the plume and in the area where the plume is migrating. However, natural attenuation is expected to reduce contaminant levels in the upper aquifer within 25 years to levels that will have no impact on the lower aquifer, and the potential for exposure to contaminants in saline ground water with Class III characteristics is low. The recommended remedial alternative combines source control Alternative 3 (removal of drums and liquids plus a clay cap) with natural attenuation, monitoring, and institutional controls.

WDR177/023